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MINISTRY OF SUPPLY

DIRECTORATE OF MATERIALS AND EXPLOSIVES

RESEARCH AND DEVELOPMENT

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PROGRAMME OF RESEARCH AND DEVELOPMENT AND PROGRESS REPORT

JANUARY 1956

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MINISTRY OF SUPPLY

DIRECTORATE OF MATERIALS AND EXPLOSIVES RESEARCH AND DEVELOPMENT

PROGRAMME OF RESEARCH AND DEVELOPMENT AND PROGRESS REPORT JANUARY 1956

This Report contains classified information of overseas origin

D.M.X.R.D.
Shell Mex House,
London, W.C.2.
February 1956

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INTRODUCTION

The programme of this Directorate, Materials and Explosives Research and Development, embraces the following establishments. In the Materials field: a Materials Advisory Service (London Headquarters), Materials Laboratory Waltham Abbey, Textiles Laboratory Farnborough, and the Tropical Testing Establishment, Nigeria. In the Explosives field: the Explosives Research and Development Establishment, Waltham Abbey.

Perhaps the most significant happenings of the past six months have concerned visits abroad or visitors to this country.

Under "Subjects of Special Interest" an instance is recounted of Anglo-American co-operation of an unusual kind. Following an exploratory visit to U.K. last Spring by Mr. Bruce Anderson of the Office of the Chief of Ordnance, Washington, U.S.A. and technical representatives of their agents, American Cyanamid Company, arrangements were made whereby a small team of the firm's chemical engineers spent several weeks at Waltham Abbey running the picrite pilot plants on continuous shift in collaboration with E.R.D.E. staff. The point of the exercise was to examine the efficiency of certain stages of the manufacturing process when operating on North American raw materials. (The stages concerned had been developed by E.R.D.E. over the past few years and actually form the basis of planned new picrite capacity at R.O.F. Bishopton.) Apart from obtaining further confirmation of the soundness of the methods, the success of this venture, probably unique of its kind, must be credited to Mr. R.G. Ross, Superintendent Chemical Engineering and his staff, notably Dr. A.W.H. Pryde, Mr. R.P. Ayerst and Mr. L.S. Herbert, who nevertheless managed simultaneously to maintain effort on other development work of very particular urgency. Dr. A. Lovecy and his group also made important contributions. Whether or not American Cyanamid Co. eventually decide to apply this experience on behalf of the American Government, the episode must be regarded as a highlight of 1955.

A symposium on ballistic-modifiers took place at Waltham Abbey during the second week of August, which was attended by about a dozen specialists from U.S.A. Mr. A. Brewin, D/C.S., E.R.D.E. organised the meeting, and whilst it cannot be claimed that a comprehensive synthesis of ideas emerged, the exchange of views was lively and valuable and resulted in each side becoming fully informed of the other's multifarious activities in this currently important field.

In June, at the invitation of General Fleury, Direction des Poudres, P.D.S.R.(D) and D.M.X.R.D. made a rapid tour of French propellant establishments. Since then an exchange of visits has taken place between E.R.D.E. and their opposite numbers in France.

A frequent obstacle to making recommendations to the Services for adoption of fuels and lubricants and hydrocarbon products generally is the lack of test facilities under actual Service conditions. With the object of ascertaining the position within B.A.O.R., D.M.X.R.D. arranged, with the assistance of D.W.D., War Office, a visit to Germany of a party of three, comprising an engineer from F.V.R.D.E., a representative of London Transport Executive (possessing specialised experience of conducting field trials) and a member of the fuels and lubricants section, M.X.6, of D.M.X.R.D. A report is about to be issued.

There has been a certain amount of unrest amongst the native employees at the Tropical Testing Establishment, Nigeria, on account of the delay in authorising wage increases and arrears of pay following the Gorsuch Award - a report and recommendations on conditions and pay in the Nigerian civil service. The situation appears to be in hand.

A paper entitled "Corrosion of Metals in the Tropics" by H.R. Ambler and A.A.J. Bain, formerly Director T.T.E. and Deputy Director, has appeared in the Journal of Applied Chemistry. In it are presented the results of several years work in tropical environments.

Turning to domestic matters, the last six months have seen a marked deterioration in the staffing position at E.R.D.E. and the continuance of a similar unsatisfactory state of things on the Materials side of D.M.X.R.D. By contrast the building programmes at Waltham Abbey have advanced satisfactorily; substantial progress has been made with the structure of the building to contain D.M.X.R.D's Materials Laboratory. At Farnborough, final completion of the Textiles Laboratory is held up pending delivery of a very large piece of test equipment, but experimental work has begun there.

January, 1956.

G. H. Johnson

Director of Materials and Explosives
Research and Development

SUBJECTS OF SPECIAL INTEREST

ANTI-CRYSTALLISING RUBBERS

Natural and many synthetic rubbers exhibit two major defects at sub-zero temperatures. One is the rapid transition at very low temperatures, below -50°C. for natural rubber, to a rigid and brittle state, caused by a decrease in molecular mobility. The second is the slow hardening with time at low temperatures, due to crystallisation of the rubber, which occurs in natural rubber at a maximum rate at -26°C.

The first of these deficiencies may be mitigated by suitable plasticisation and work at the British Rubber Producers Research Association (Fletcher, Gent and Wood: Third Rubber Technology Conference, 1954) has shown how this may be achieved without undue deterioration in physical properties. Plasticisation does not, however, prevent the rubber from crystallising on storage at moderately low temperatures.

Crystallisation is caused by the alignment of portions of adjacent molecules, forming nucleation centres which promote crystal growth, so in turn causing further structural alignment. This brings about a relaxation of stress in a stretched sample and, ultimately, an actual increase in length.

From this physical picture it can be predicted that randomly spaced irregularities attached to the rubber molecule should retard crystallisation, since they would prevent the formation of nucleation centres. Vulcanisation acts in this way and some types of vulcanisate are highly resistant to crystallisation, unlike raw rubber. However, Service demands on rubber products in this respect are becoming increasingly stringent and the need exists for greater retardation of crystallisation than is possible by such means.

Anti-crystallising rubbers are chemically modified rubbers developed by the British Rubber Producers Research Association to overcome the inherent tendency of natural rubber to crystallise.

Modification of the rubber has been carried out by treatment with small amounts of organic thiol acids and products have been obtained which have rates of crystallisation less than one-hundredth of that of a comparable unmodified vulcanisate.

Addition of the thiol acid to natural rubber has been made in two ways:-

(1) To the rubber during compounding,

(2) To the latex followed by coagulation, etc.

The first method is obviously the more convenient since in principle the rubber manufacturer should be able to carry out the reaction using supplies of normal rubber. Owing, however, to the formation of a by-product which is an extremely potent producer of premature vulcanisation ('scorch') such compounds cannot be recommended for factory use (unless the by-product can be removed by solvent extraction). Furthermore, the reaction in the mill is notably inefficient since it is so rapid that non-random distribution occurs. This, coupled with loss of reagent by the side reaction, leads to inadequate retardation with less than 3 parts of reagent per 100 parts of rubber.

The second method, addition of thiol acid to natural rubber latex, has been successfully achieved by B.R.P.R.A., although further development is necessary to enable large scale preparation to be carried out. In latex the additive can be well dispersed before reaction occurs and there is little or

no by-product. Consequently, the efficiency of action per unit of additive is very greatly increased and retardation ratios of exceeding 100 to 1 have been obtained by the addition of less than 0.2 parts of reagent per 100 parts of rubber. Furthermore, the scorch problem disappears since no appreciable amount of the by-product is present in the dried coagulum.

Some difficulty has been experienced because of the marked tendency to oxidative degradation during the reaction and during the drying of the product, but satisfactory small batches of material have been produced and large scale production is being tried.

The physical properties of the vulcanisates made from the modified rubber are, at the moment, slightly inferior to those of comparable vulcanisates made from standard rubber, but further work is in hand to improve these. The main deficiency appears to be in the ageing characteristics, probably due to the oxidative degradation mentioned above and a reduction of this, on which work is being carried out, should lead to an improvement. The work is covered by Patents granted to B.R.P.R.A.

Arctic trials on both test samples and components have been planned and it is hoped that these will commence in January 1956.

CEMENTS FOR SEALING AMMUNITION

Cements are widely used in ammunition assemblies for two main purposes, the more important of which is to seal the joints against ingress (or egress) of liquids and vapours, especially water, whilst the other use is to form a mechanical bond between the cemented components. In general, the joints to be sealed are screw-threaded.

Cements for use in proximity to explosives must set at room temperature. Such cements may be divided into three classes:

(i) Those which dry by evaporation of solvent, the solid residue remaining soluble.

(ii) Those which first dry by evaporation of solvent, and subsequently irreversibly gel and/or polymerise.

(iii) Those which set by chemical reaction and do not need a solvent.

Cements of the first two classes have the disadvantage of excessive contraction during drying; this causes the formation of channels in or porosity of the residual solid and results in poor sealing efficiency; they also dry very slowly. Cements which harden by chemical reactions are the only ones which can have s satisfactorily low contraction during setting and set sufficiently quickly.

The current Service lead free chemically setting cements (R.D.1241B, R.D.1242B, R.D.1243B, and R.D.1248) are soaps loaded with mineral fillers, which set by the reaction between magnesium oxide and oleic acid. The reactivity of the ingredients is variable and this variation gives rise to a pot life which may be either too short or too long; frequently setting times are also too long. The magnesium oleate cements, when set, are brittle and liable to fracture on rough usage, although they contain a plasticiser in varying proportions. Their contraction on setting, although less than that of cements containing solvents, is of the order of 10% by volume.

A survey has been made of industrial cements and adhesives in order to find materials superior to the Service compositions. The field is

strictly limited in that any cement for use in ammunition must be compatible with high explosives or propellants and preferably with both. One of the most promising types of material is a resin that is based on the phenols derived from cashew-nut-shell liquid. These phenols can be polymerised to form resins which react at room temperature with paraformaldehyde, producing rubbery gels. A particular grade of cashew-nut-shell polymer (H.8160, manufactured by British Resin Products Ltd.), has been found satisfactorily compatible with explosives, except amatol.

A cement, R.D.1286, containing 100 parts by weight of this resin with 6 parts by weight of paraformaldehyde, has been developed and its physical and chemical properties have been compared with those of the Service cements. R.D.1286 is more flexible, its contraction during setting (about 2% by volume) is much less and it is a better thread-sealer. It makes good seals over a wider range of temperature and is generally stronger than Service cements. Its pot life is much less variable and its setting time is considerably shorter.

The use of R.D.1286 in a number of Service stores is under consideration and it is hoped that it will ultimately replace the Service magnesium oleate cements. It is proposed to pack the two components of the cement in convenient dual containers.

A report describing the development of this cement has been prepared.

THE DE-LEADING OF GASOLINE

In the event of war the only grade of gasoline likely to be supplied in the field is M.T.80 which may contain up to 3.6 ml/Imperial gallon (3.0 ml/U.S. gallon) of tetra-ethyl lead (T.E.L.).

Fighting vehicles have been designed to operate entirely successfully on fuel containing 3.6 ml/I.G. of T.E.L. Normal commercial grades of gasoline in U.K. contain only 1.8 ml/I.G. or less of T.E.L. and requisitioned commercial vehicles may need to be modified before they will operate satisfactorily on high lead content gasoline; the fitting of new valves made from improved steels and valve rotators would be the only necessary modifications.

Stationary engines and certain gasoline fuelled heating and lighting equipments, however, have their life drastically reduced if they operate on high lead content fuel. With flue-less type heating or cooking equipment the toxic hazards from the lead compounds in the products of combustion are not necessarily negligible although evidence on this point is not conclusive.

For stationary engines the Services rely on selected commercial types and these engines, as normally supplied, have a short life before top overhau becomes necessary if operated on gasoline containing 3.6 ml/I.G. of T.E.L.: exhaust valve burning and the build up of engine deposits being the symptons or the causes of failure. Here again, some success has been achieved by simple engine modifications including improved valve steels and valve rotators with some redesign of valves and valve seatings. The extension of the life of a stationary engine by increasing its resistance to the effects of lead deposits does not, however, prevent the general build up of deposits in the engine. After some time (from about 300 hours onwards) trouble may be experienced through the breaking away of pieces of deposit from the cylinder head which is most likely to occur on engine shut-down. These piec can jam the piston or valves and prevent the engine from restarting.

The design of heating equipments to operate on high lead content gasoline is well advanced but designs could probably be simplified, maintenance could be reduced and over-all efficiency improved if a lead

free or low lead content gasoline were used. Gasoline burning lamps do not appear to be very efficient when operated on high lead content gasoline and de-leading of the fuel before use may be the only acceptable solution for this particular application.

It was after consideration of the problems associated with the use of high lead content gasoline in the equipments mentioned above that it was decided that the possibility of de-leading Service gasoline in the field should be investigated.

Many methods have been proposed and investigated in the past and several papers and patents have been published on the subject. After reviewing these the scope of the present work was limited to the examination of those techniques which might be suitable for field use. The employment of toxic or corrosive chemicals was rejected as well as methods involving comparatively complex plant (e.g. cracking or distillation techniques).

Absorbent materials were thus the only ones worthy of investigation and an Extra-Mural Research Contract was placed by D.M.X.R.D. with the British Petroleum Research Station for this work. It was hoped that a simple percolation process such as pouring the gasoline from one jerrican through a filter device into another would be all that was required. This was not, however, found to be practicable as all the granular or pelleted absorbents were comparatively inactive; if powdered materials were used the percolation was too slow. About twenty absorbents such as bauxite, charcoal and various clays and ion exchange resins were examined, but the only material with any marked activity was a sulphuric acid activated montmorillonite clay marketed by the Fullers Earth Union. The investigation included the variation of the reduction in T.E.L. content with both contact time and quantity of clay and a treatment was selected which was considered the best compromise for practical use. This involved shaking or stirring the gasoline with the powdered clay ($\frac{1}{2}$ lb Clay to 1 gallon of Gasoline) for 15 minutes, and methods have been developed for carrying this out in a jerrican and also on the forty-gallon drum scale.

Whether even the simplest practical technique that can be developed will be acceptable to the equipment user, depends on whether the treatment is less nuisance than the extra maintenance that results from operation on high lead content gasoline. Trials on certain stationary engines and gasoline fuelled heating and lighting equipments are at present in progress and will help to decide this point. These trials will also demonstrate whether other slight changes in the gasoline which take place, in addition to the reduction in lead content, have any adverse effect on the performance of the equipments.

THE MANUFACTURE OF GUANIDINE NITRATE FROM NITROLIM

Collaboration with U.S. Army Authorities

Since 1948 E.R.D.E. has done much work on the development of new methods, and the improvement of existing ones, for the production of "picrite", i.e. nitroguanidine of crystal size suitable for incorporation in gun propellants. Two stages of the manufacture from nitrolim have been substantially improved. These are:-

(i) Conversion of nitrolim to guanidine nitrate by reaction with hot aqueous ammonium nitrate (the so-called Direct Fusion process),

(ii) Conversion of guanidine nitrate to nitroguanidine with the aid of oleum and recycling of spent acid to the nitrator (low-ratio nitration process).

Both stages have been studied on a fair scale and continuously operated pilot plants have been run for long periods to prove their chemical engineering feasibility. These E.R.D.E. developments are included in the new picrite plant under erection at R.O.F. Bishopton.

In September, 1954, D.M.X.R.D. was informed that the U.S. Army was considering putting up additional picrite capacity and wished, before deciding to copy the Welland plant, to explore the possibilities of any new methods available, either in U.S.A. or U.K. The Office of the Chief of Ordnance was advised to consider the two E.R.D.E. developments enumerated above. O.C.O. later placed a contract with American Cyanamid Co. to design and erect the new plant.

The first important question that arose was whether the E.R.D.E. direct-fusion process could replace the equivalent Welland stages, conversion of nitrolim to dicyandiamide, and treatment of the latter with ammonium nitrate in liquid ammonia solution at high temperature and pressure to give guanidine nitrate. A delegation from American Cyanamid Co. came over in March 1955 to discuss all aspects of the E.R.D.E. developments, but more particularly direct-fusion. Discussions were held in Shell Mex House and at E.R.D.E. and the visitors studied comprehensively the pilot plants in operation.

Later it was proposed that, in order to save the time which would be involved in proving the direct-fusion process in America, their technicians should run the Waltham Abbey plant on North American nitrolim. This was agreed. A comprehensive programme of plant trials, and of associated laboratory preparative and analytical work, was drawn up between E.R.D.E. and representatives of O.C.O. and the firm. Arrangements were made to send over supplies of nitrolim from two sources, Oklahoma and Niagara. Three or four chemical engineers from Cyanamid came over to assist the E.R.D.E. staff run the pilot plants continuously.

The trials at E.R.D.E. extended over about three months and were entirely successful. Nitrolims from North America behaved similarly to the Norwegian and Kenfig materials normally used here. The expected yields of guanidine nitrate were obtained in five-day continuous runs but there was a large loss of ammonium nitrate, traced ultimately to a fault in the evaporator which allowed some of the circulating liquor to escape through the steam trap. Laboratory work had indicated that an accumulation of deleterious impurities in the re-cycled ammonium nitrate solution was most unlikely to occur.

Trials of the low-ratio nitration process were much less comprehensive but the plant was run continuously for three days. The expected yield of nitro-guanidine was obtained.

These trials have confirmed the earlier results of E.R.D.E. The yields, calculated as per cent of theory on the total nitrogen content of the nitrolim, together with recent Welland results provided by the American Cyanamid Co. for comparison, are tabulated below:

Stage	E.R.D.E.	Welland
(1) Nitrolim to guanidine nitrate	91	82
(2) Guanidine nitrate to nitroguanidine	94	89
(3) Nitroguanidine to picrite	98	98
(4) Overall yield - Nitrolim to picrite	84	71

For fair comparison the E.R.D.E. yield (1) has been corrected for guanidine nitrate in solution in the recycled ammonium nitrate liquor, a procedure justified by the shortness of the pilot-plant runs. Without this correction, yield (1) is 87% and yield (4) 80%.

There are other advantages of the E.R.D.E. processes. The intermediate guanidine nitrate is purer; it contains virtually no melamine (Welland 1.25%) and less ammonium nitrate, about 2% in place of over 5%. The sulphuric acid usage in the nitration stage is much less; 20% oleum equivalent to 1.8 parts of sulphuric acid per part of picrite, compared with 3.0 parts of sulphuric acid.

As a footnote to the above, it should be added that in the E.R.D.E. pilot plant, guanidine nitrate is finally crystallised from the reaction liquor in a scraper-cooler. A disadvantage of this equipment is the low heat-transfer coefficient, and on American scale of production the area of cooling surface would be prohibitively large. American Cyanamid Co. therefore decided to examine the behaviour of a simulated plant liquor in a large vacuum crystalliser at Welland. An E.R.D.E. representative was invited to U.S.A. in October to participate in the trials. The results were entirely satisfactory. The crystalline guanidine nitrate filtered easily and its contamination with ammonium nitrate was low.

Because of the large concentration of ammonium nitrate in the plant liquor, a good vacuum, obtained by steam ejectors, was necessary to produce adequate cooling. The steam consumption was therefore high and adoption of similar equipment in U.K. would be expensive.

PRESSED CHARGES

"Pressed Charges" are a development of I.C.I.'s gas producing compositions based on the catalysed decomposition of ammonium nitrate (A.N.), guanidine nitrate (G.N.) or mixtures of the two. The production of such charges is essentially very simple: the ammonium (and/or guanidine) nitrate is mixed intimately with the catalyst (usually ammonium bichromate) and the dry mixture is consolidated under heavy pressure (5 tons/sq.in.).

Charges of this type were used first in "power cartridges" to generate gas under pressure for a variety of applications. The charges were end-burning, and were pressed directly into cylindrical steel cases lined with gasket material to protect the case and to prevent side-burning.

For rockets requiring large (15-20 ins. diameter) charges, which burn outwards from the surface of a star-shaped longitudinal perforation, such a system is unsuitable, because of differential thermal expansion over the wide temperature range required. The propellant is therefore pressed in

cylindrical, segmented moulds into blocks ("cheeses") which are an easy fit in the rocket case at the lowest temperature concerned. The central performation is produced by pressing round a star-shaped mandrel. The inhibition can be a layer of incombustible material on the surfaces of the cheeses as required, the whole being pressed together in one operation. Satisfactory bonding between inhibitor and propellant was achieved by including in the inhibitor a proportion of guanidine nitrate, the remainder being kaolin.

The existence of several crystalline forms of ammonium nitrate and the readiness with which each changes to another at a well-defined temperature, with an appreciable and disruptive volume change is a factor of importance in the use of ammonium nitrate in the compressed form. The phase-change at 32°C. (about 90°F.), particularly troublesome in this connection, has been found to be largely suppressed if the ammonium nitrate is replaced by a 9:1 mixture with potassium nitrate (K.N.). Whilst simple dry mixing of the A.N. and K.N. appeared at first to be adequate, it has now been found necessary to effect a degree of mixed-crystal formation by mixing the salts with water in a heated incorporator and continuing the agitation until the mixture is dry.

Because a sufficiently large press was not available in an explosives area, the earlier large pressed charges for rockets were made of a substantially non-explosive mixture, "M.R.C.12" comprising, A.N./K.N., G.N. and catalyst in the proportions 13:83:4, the catalyst being a 3:1 mixture of ammonium bichromate and cupric oxide. Charges of M.R.C.12 have given satisfactory results, both static and in flight, in the "Rat Catcher" motor for a "Red Shoes" test vehicle.

After a 1500-ton (dead load) press had been installed at Ardeer, more energetic charges (that is, containing more ammonium nitrate) were developed. Compositions R.C.5 and R.C.6, essentially 36:62 mixtures of A.N./K.N. and G.N., were developed for the "Elkhound" motor, also for the "Red Shoes" weapon. The two compositions were adjusted to differing burning rates by variation of the added catalyst and the two were pressed together in a transverse configuration so that the whole charge was consumed without leaving unburnt "slivers"; this "birate" configuration increased the available energy of the charge and produced a sharp "cut-off" at the end of the burning.

In the early stages of these developments, I.C.I. were urged to find an alternative to G.N., which was then in short supply; R.C. type compositions go part of the way towards meeting that requirement. Although G.N. is now plentiful, the best fuels, theoretically, for ammonium nitrate would clearly be either elemental carbon or hydrogen or an endothermic compound of the two which would contribute the energy of its own decomposition, as well as that of the combustion of its elements in the oxygen of the ammonium nitrate. A further advantage of a fuel without oxygenated groups is that the propellant based on it can accept a correspondingly higher proportion of the cheap (3d. per lb.) ammonium nitrate oxidant.

In searching for alternatives to G.N., processing feasibility must be considered as well as energy contributing factors. Of the many substances examined, anthraquinone, acetanilide, dinitronaphthalene, p-nitroaniline, bitumens, pitch, anthracite and aniline-formaldehyde resin ("panilax") have shown promise in varying degrees. Recent developments, however, have used high melting synthetic hydrocarbon waxes as fuels for the A.N.; typical compositions are wax:A.N./K.N.:: 8.5:89.5 (A.F.W.1) and 6.5:91.5 (A.F.W.2), each with two percent of ammonium bichromate and from 0 to 3% of china clay. These compositions, in "bi-rate" conjunction, are being used to develop the "Staghound" charge, which could power either the "Red Shoes" sustainer or an aircraft A.T.O. motor.

For satisfactorily uniform consolidation, the compacted blocks of propellant must have lengths not greatly exceeding their diameters. Each

motor of the size concerned must therefore contain a number, generally three, of such blocks, each weighing about 200 lbs. Initially, each block or "chesse" was provided with an inhibiting layer of G.N./Kaolin at each end in addition to the external cylindrical surface; each pair of cheeses was separated by a rubber gasket (star-perforated) and the whole charge was held in position by compression springs in a sort of "bedstead" at the front end of the motor body.

With compositions containing very high proportions of ammonium nitrate, difficulties were encountered in obtaining satisfactory matching between the thermal properties of the propellant and those of the inhibitor, which tended to crack on temperature cycling, through differential thermal expansion. With the wax compositions it was found also that the spring device caused slow longitudinal shortening, with corresponding spreading in the diameter of the cheeses.

Attention has therefore been turned, with promising results, to the provision of an inhibitor in the form of a tubular rubber sleeve stretched over the assembled cheeses, followed by a wrapping with cellulose acetate sheet, cemented with acetone as in the making of "beakers" for C.D.B. propellant. Integral inhibition with inert powder is omitted except at the forward end of the cheese farthest from the venturi. At the venturi end inhibition is provided by a star-perforated, thick walled shallow dish of C.A., which becomes integral with the C.A. wrapping later applied. A circumferential groove is then cut in the cylindrical wall of the dish to house a clip which holds the charge in the motor without compressing the propellant.

These modifications, the change to more energetic compositions and the addition of domed ends to the outer cheeses, have resulted in progressive increases in the total impulse of the charge in the same motor from 85,000 (Ratcatcher) to 116,000 (Elkhound) and 135,000 (Staghound) lbs.-second. The corresponding Specific Impulses of the three compositions at 400 p.s.i. are around 160 (M.R.C.12), 175 (R.C.) and 190 (A.F.W.1).

The advantages of pressed propellants, lie in their safety, chemical stability and economy.

Regarding safety, the loose compositions can be detonated, but are not prohibitively friction sensitive. The pressed blocks, however, cannot be detonated by blasting gelatine primers, as has been repeatedly demonstrated. When a motor filled with a block of R.C. composition is roasted only a pressure burst results and fragments, generally large, of the block are projected, to fall around unignited. Trials have indicated also that no more than a pressure burst is likely in the event of an ignition during the pressing operation. More work on these lines is, however, required with the wax compositions.

Regarding chemical stability, the pressed compositions compare rather with typical Service H.E.s than with colloidal propellants; the Vacuum Stability test is thus applicable. It appears that pressed charges would not require the periodic inspection and proof procedure necessary with cordites; neither should they be liable to cracking due to formation of gaseous decomposition products during hot storage.

The economy of pressed charges follows not only from their high content of ammonium nitrate (£25 per ton) but also from the relative simplicity of the pressing operations: dry mixing, pre-caking, granulation, final pressing - all largely non-hazardous, and none involving a chemical process. The cost of a pressed charge filling for a typical A.T.O. motor should be less than one-third of that of the corresponding cordite charge.

Objections to pressed charges lie in the hydroscopicity of ammonium nitrate, the relatively low energy content of propellants in which it forms the oxidant and the limited resistance of the block to rough usage.

The hydroscopicity of ammonium nitrate requires the relative humidity of the process room atmosphere to be strictly controlled. In practice, this has not caused serious difficulty in the wettish climate of south west Scotland, but cheeses must be well protected, e.g. in polythene bags in sealed containers, for transport and motors must be charged in a dry atmosphere and hermetically sealed for storage. Impact resistance of the pressed R.C. compositions has recently been found to be markedly dependent on the dryness of the cheeses, too low a residual moisture content leading to increased fragility. This effect may not be easy to control; more work is required, especially on the wax compositions, in which the diffusibility of residual moisture may be less, whilst the rubber/C.A. wrapping may help.

The low energy content of ammonium nitrate propellants is inherent. It can be improved only by including more energetic oxidants and/or endothermic fuels, e.g. perchlorates or nitrate-perchlorate mixtures at increased cost and complication and probably with some sacrifice of safety. The drawback of oxygenated fuels, already mentioned, is the lower proportion of cheap oxidant in the finished composition that their use would entail; solid acetylenic hydrocarbons are worth examination as endothermic fuels.

The relatively low mechanical strength of pressed charges is scarcely surprising in view of their structure which lacks the continuum which exists in both colloidal and plastic propellants. The support and cushioning afforded by the new wrapping may make this objection less important. Improvement could be looked for by using a continuum-providing fuel. Waxes may do this to some extent but are not themselves mechanically strong; thermo plastic and thermo setting resins are obvious possibilities, but the manipulation of pasty mixtures of salts and liquids and curing by hot-pressing would mean radical departure from the simple pressed-charge concept.

Regarding ballistics, the pressed-charge propellants are generally slow burning (0.06 to 0.2 in. per second) and therefore applicable to sustainer rather than boost motors. Their ballistic temperature and pressure dependencies are not unacceptably great. No useful platonisation effects have so far been discovered with these compositions; they have, however, the advantage that the rate of burning of a given fuel/oxidant mixture can be controlled by varying the content and/or nature of the catalyst, without varying the energy content of the propellant; blending of rate assessed batches to achieve exactly the desired performance is thus facilitated.

Pressed charges cannot at present compete with case-bonded propellants when maximal total impulse is imperative. They offer, however, simpler manufacturing and motor filling techniques, and may find effective application when a comparatively cheap propellant is essential because of th requirement for large numbers of motors, together with a filling operation which can take place elsewhere than in a filling factory. Motors for assisted take-off of aircraft, using sturdy bodies which can be recharged repeatedly, possibly after jettisoning, seems a likely field for pressed charges; this application is under active consideration.

Notes on the Standardised Symbols Employed

Col.3 Service Project Number or other Reference

Where the item being reported is only contributory to a Service Requirement, the reference is enclosed in brackets.

Col.4 Priority, Effort and Category

Priority, (P)

Items in aid of Service Requirements are assigned to the following Priority Classes:-

Class 1 - Projects of such importance that, in the event of unexpected delay, staff and resources should be withdrawn from projects in lower classes in order to effect completion in time.

Class 2 - Projects of importance on which the staff and resources necessary should be employed subject to the over-riding needs of projects in Class 1.

Class 3 - Projects on which resources remaining after meeting the requirements in Classes 1 and 2 should be deployed.

Class 4 - Projects to which no effort is to be devoted at present.

Internal priorities for basic work, particularly Research, carried on under the authority of the Controller of Munitions, are assigned a Basic Priority Classification "A", "B" or "C", roughly equivalent to Priorities 1-3 respectively.

Effort (E)

A - Item is so fully staffed that progress would not be accelerated by any increase.

B - Sufficient staff has been allocated to the item to ensure satisfactory progress.

C - Progress on this item is retarded by the lack of specialist staff.

D - Item to which staff is allotted when work of higher priority is held up for reasons unconnected with staff.

E - No staff can be made available for this item at present.

R - Staff are allocated for short-term jobs as the needs and priorities of the moment demand.

Category (C)

The Category assigned to an item is that used in the M.O.S. internal planning and progressing system used in the D.P.P.(E.E.) quarterly returns.

Category 1 - Requirements for Service and Other Departments
- 1.1 - Dated Projects
- 1.2 - Undated Projects
- 1.3 - Post-design Services
- 1.4 - Unscheduled jobs (i.e. officially requested by a Department, but not on their list of requirements).

Category 2 - Requirements Internal to M.O.S.
- 2.1 - Basic and Applied Research and Development
- 2.2 - Development and Design of Test and Laboratory Equipment.

In the case of sub-categories 1.1 and 1.2, items are further annotated as 'A' projects (1.1A, 1.2A) or 'B' projects (1.1B, 1.2B).

'A' projects are those which appear on the Service or other Departments' list of requirements and for which the Establishment indicated in col. 5 is fully responsible.

'B' projects are items on which the Establishment is working, but which are consequential to 'A' projects for which the main responsibility lies with another Establishment.

MATERIALS

				Abbey.	60°C dry or 60°C and 100% R.H. The trial is continuing.
	(b) Actinic degradation of textile fibres	Recommendation of 4th Commonwealth Defence Conference on Clothing and General Stores	3 B	T.T.E., Nigeria. C.I. (Didcot)	A further set of yarns has been prepared and shipped to T.T.E. for exposure at Kano. The trial at Didcot has started.
2 **Development of New Fabrics**					
2.1 **Body Armour**	Properties of textile fibres and yarns at high rates of strain EMR. 7/Gen/1435	W.O.P.S. 56	1 C	British Rayon Research Assoc.	The first interim report from the Brit. Rayon R.A. describes an apparatus which has been built for studying stresses in textile filaments when extended at rates of the order of 100 ft./sec. The results of some initial experiments are discussed.
2.2 **Clothing Fabrics**	(a) Application of man-made fibres to Service textiles. Investigation of ternary fibre mixtures in which wool is diluted with a cheap weak fibre and reinforced with a strong fibre such as nylon or Terylene EMR. 7/Exptl/567	W.O.P.S. 45	3 B	D.M.X.R.D. Leeds University	The wear trial on knitted vests made from wool and varying proportions of nylon and viscose has been completed. The testing has begun of 84 different serges woven by Leeds University from yarns containing wool, nylon and one or two of the following - Ardil, Rayolanda (modified viscose staple) and Celafibre (cellulose acetate staple). Difficulties were encountered in

				producing cloths containing Ardil and their strength was inferior to that of the standard all-wool control. The other fabrics were all stronger than the standard serge, those containing Rayolanda having the highest tensile strength. On the other hand, the introduction of Celafibre considerably improved wind resistance. Consideration is being given to a further contract with Leeds University to extend this work to ternary blends containing viscose staple and to the use of Terylene as an alternative to nylon.
(b) Development of cotton and wool fabric assemblies for the combat suit EMR. 6/Text/9166 EMR. 6/Text/9996	W.O.P.S. 45	3 B	British Cotton Industry Research Assocn. Wool Industries Research Assocn.	A report has been prepared for the 5th Commonwealth Conference entitled "Rain and Wind Resistant Properties of Unlined and Lined Fabrics for Combat Clothing". In it the E.M.R. work undertaken by the British Cotton Industry Research Association and the Wool Industries Research Association has been summarised and discussed. It has been shown that a considerable improvement in the water repellency of the present combat suit could be achieved by replacing the present lining (Gaberdine 3170) by a close cotton cloth. Another possibility which requires further consideration, is the use of an unlined cloth, e.g. Q.1 (see 2.2 (c)). Wool fabrics made by W.I.R.A., although possessing better wind resistance and superior water repellent properties to the present battle-dress serge, were found to have low tear strengths and cannot, therefore, be recommended.

I **TEXTILES** (Contd.)					
	(c) Improvement of tear strength of cotton cloth	W.O.P.S. 45	3 B	British Cotton Industry Research Assocn.	As a result of previous work done by the B.C.I.R.A. (see 2.2 (b)), a further E.M.R. contract will be placed with the Association for improving the tear strength of Q.1 cloth. The research programme involves the weaving of some 30 different cloths, varying in composition (some will contain nylon), in the quality of the cotton used and in their construction.
	(d) Fabrics with low air permeability. Gannex fabrics	W.O.P.S. 45	3 B	D.M.X.R.D. C.S.E.E.	An order has been placed with Kagan Textiles for 200 yards of Gannex fabric. Most of the delivery will be an assembly made up with an outer cotton and inner wool cloth, but some will be made in a similar construction with an outer cotton/nylon fabric.
2.3 **Stores Fabrics**	Development of a cheaper and lighter fabric for gasmask containers	Recommendation of Advisory Panel on Chemical Defence Equipment Production.	3 B	D.M.X.R.D.	Samples were submitted to A.D./C.D.P. in July. No comments have been received.
2.4 **Ammunition Textiles**	(a) Exploration of new textile fibres for ammunition purposes	Ordnance Board (Proc. 37.133)	3 B	D.M.X.R.D. E.R.D.E.	The Terylene fabric to be used in the rough usage and firing trials, to be arranged by the Ordnance Board, is being selected from several cloths which have been submitted by the manufacturers. Compatibility tests on the anti-static agents used on Terylene fabrics are being arranged with E.R.D.E. Trials on calcium alginate fabric have shown it to be unsuitable for the production of cartridge bags.

	(b) R.C.R. cloth for B.L. cartridge fabrics	Ordnance Board	3 B	D.M.X.R.D.	The use of viscose fabrics for ammunition textiles is being reviewed, in particular, (a) the possibility of using rayon of 3 oz. and 6 oz. per square yard for smaller ammunition and (b) variations in the urea formaldehyde treatment. Hitherto the urea formaldehyde treatment applied to R.C.R. cloth for B.L. cartridge bags has been the standard commercial crease-resisting finish. This is not necessarily the most suitable for this requirement and the merits of other urea to formaldehyde ratios and condensation catalysts are being tested. It will be necessary to establish the acceptable limit for free formaldehyde and to develop a test method.
3 Coated Fabrics					
3.1 Capes, G.S.	Examination of new coatings	W.O.P.S. 45 (WO/DOS/186)	3 B	D.M.X.R.D. and Industry.	Work on improving the low temperature properties of Calaroc is being continued at I.C.I. Resin Service Department.
3.2 Protective Clothing	(a) Development of a fabric providing protection against H.T.P.	R.A.E./R.P.D.	3 B	D.M.X.R.D.	Several samples of p.v.c. coated Terylene have been tested and a recommendation on the most suitable material made to R.A.E./R.P.D.
3.3 Light-Weight Artillery Covers	Replacement of flax canvas by a light-weight fabric	Request of D.G. of A.	3 C	D.M.X.R.D.	This project is now in abeyance owing to lack of staff.
4 Flame and Radiant Heat Protection	(a) Development of laboratory equipment for simulating the thermal effects of an atomic explosion	W.O.P.S. 209	2 C	D.M.X.R.D. Fire Research Station.	The information obtained from the visit to Rochester University has been issued as D.M.X.R.D. Report MX5/8/55, "Experimental Methods in Studies of Flash Burn".

I **TEXTILES** (Contd.)					The carbon arc/elliptical mirror equipment at the Fire Research Station is now working satisfactorily and giving intensities up to about 15 calories per square centimetre and the extensive programme of investigations has now begun. The equipment has been made available to R.A.E. and to C.D.E.E. for certain urgent tests in connection with Operation Buffalo. Preparations for Operation Buffalo have made heavy demands on staff-time during the last six months. Exposure frames have been designed and made. A wide range of samples of textiles, plastics, rubbers, paints, packaging materials etc. has been collected, cut to size, identified and mounted. Arrangements have also been made for the shipment, exposure and reporting of certain items of War Office and Ministry equipment for which the materials team is responsible. So far the materials team is up to schedule.
	(b) Development of a permanent flame-proofing process	W.O.P.S. 209 (DOS 1031)	2 C	D.M.X.R.D. and Industry	The investigation of the tetrakis hydroxymethyl phosphenium chloride (THPC) process continues. Samples of cotton sheeting, gaberdine 3170, cotton sateen, drill No.2 and cotton duck have all been treated with T.H.P.C. and are being examined for strength, flameproofness and permanence to laundering.
	(c) Proprietary flame-proofing processes	W.O.P.S. 209 (DOS 1031)	2 B	D.M.X.R.D.	The assessment of the "Aflamman" and "Antipyr" processes has not yet been completed. Arrangements are being made for a full scale trial of the application

					of the improved "Erifon" process to certain selected Service fabrics. Samples of jute hessian and twill sacking flame-proofed by a process developed by the British Jute Trade Research Association have been received and are under test.
5 **Rot Resistance**	(a) The comparative assessment of standard British and other processes of rot-proofing cotton	W.O.P.S. 100	3 B	D.M.X.R.D. T.T.E., Nigeria. C.I. (Didcot) and various U.K. laboratories.	A report has been prepared for the 5th Commonwealth Conference entitled "The Assessment of Certain Textile Preservative Processes". Although the investigation has not yet been completed, it is possible to draw the following conclusions from the data so far obtained:- (a) chromium compounds do not give any protection to cotton against microbiological attack; (b) most of the treatments based on copper and the two organic agents (pentachlorophenyl laurate and dihydroxy-dichloro-diphenyl methane, G.4) accelerate the actinic degradation of cotton. It was also established that p.c.p.l. is not fast to leaching and, for this reason, G.4 may be preferred for some applications. Copper-8-hydroxyquinolate was found to give good results under all conditions.
	(b) Rot-proofing of cordage	W.O.P.S. 100	3 B	D.M.X.R.D. T.T.E., Nigeria A.I.D. C.I. and Industry	The exposure trials continue. The fourth set of samples (after eighteen months' exposure) has been withdrawn from Port Harcourt, Lagos and Kano sites at T.T.E. and the residual tensile strengths and copper contents determined. It is proposed to issue a report after the results of the next withdrawal are available.

I **TEXTILES** (Contd.)					A further trial has been arranged in which lengths of treated and untreated ropes are partly submerged in tropical sea water. The first ropes to be exposed were lost at T.T.E. through rough weather and the trial has begun again with fresh samples.
6 **Water Repellent, Shrink Resistant and Other Finishes**	(a) Water repellent finishes for wool	W.O.P.S. 45	3 B	D.M.X.R.D.	Tests are at present being made on pieces of battle-dress serge treated with silicone applied under two different sets of conditions and with Quintolan W.
	(b) Water repellent finishes for cotton	W.O.P.S. 45	3 B	D.M.X.R.D.	A report has been prepared for the 5th Commonwealth Conference entitled "Water Repellent Finishes on Cotton". It has been shown that the performance of cotton sateen, which is used for making up the combat suit, is only slightly better when finished with "permanent" water repellent finishes than when treated with non-permanent finishes of the aluminium soap/wax emulsion type. The efficiency of all finishes is reduced by weathering (exposure to the London atmosphere), and by dry or wet cleaning. It has, therefore, been suggested that future specifications should not stipulate the use of Velan, a proprietary "permanent" finish, but that a performance test should be included. Furthermore, arrangements should be made for cotton garments to be refinished with a non-permanent agent after laundering. A modification of the standard silicone finish developed by the Bradford Dyers' Association is being examined.

	(c) Shrink resistance of denims	W.O.P.S. 45	3 B	D.M.X.R.D. British Launderers' Res. Assocn. and Industry	A length of denim differing in construction and finish from the standard has been produced with the object of overcoming the shrinkage problem and is now being tested. It has been shown that denims taken from M.O.S. stock shrink excessively, but members of the Controlled Compressive Shrinkage Association maintain that on leaving their machines the denims are fully shrunk. A programme has, therefore, been worked out with the C.C.S.A. and with the B.C.I.R.A. for checking whether bulk quantities of fully shrunk denims remain unaltered during storage.
7 **Textile Test Methods**	(a) Wear testing	W.O.P.S. 45	3 B	Materials Laboratory, Farnborough	A Technical Note is in preparation in which experiments with the Stoll-Quartermaster Universal Wear Tester are described and the value of flat abrasion and flex abrasion tests with this apparatus for assessing the wear characteristics of service fabrics is discussed.

I PULP AND PAPER

1 Pulps					
1.1 Wood Pulps for the Manufacture of Nitration Paper	To develop a more assured, and strategically less vulnerable, source of supply	Explosives Development Policy Committee	2 C	D.M.X.R.D. E.R.D.E. R.N.P.F. (Caerwent) J. & J. Makin Ltd.	Following certain criticisms by E.R.D.E. of the nitration behaviour of the papers made from rayon/bleached sulphate blends, E.D.P.C.(A) recommended that a further papering trial should be carried out immediately to determine whether these objections could be overcome (a) by heavier beating of the pulps (b) reversion to 16 lb. D.C. substance. This trial has taken place and paper has been produced at three different degrees of beating. A batch at 20 lb. D.C. was also made for investigation of the effect of substance.
2 Papers for Special Applications					
2.1 Water-Proofing of Maps		Director of Military Survey, War Office	3 B	D.M.X.R.D. and Industry	A sample container of the "Aerosol" type which delivers a spray of nitrocellulose lacquer has been submitted to Director of Military Survey for consideration. It is reported that this offers a very attractive method of water-proofing maps in the field and a large-scale field trial is to be arranged.

III **TIMBER**					
1. **Preservative Treatments**					
1.1 **Improved Methods of Surface Treatment**	Performance of pentachlorphenol solution	W.O.P.S. 100	3 B	D.M.X.R.D. F.P.R.L. C.I.	A 5% solution of pentachlorphenol has now been added to the preservatives approved for the surface treatment of timber and is covered by specification C.S.2714.

IV PACKAGING MATERIALS					
1 General, Committees and Specifications					
1.1 Joint Service Research and Development Committee on Packaging Materials	Critical review of Service packaging problems with special reference to materials aspects		3 B	D.M.X.R.D.	The Committee reviewed Extra-mural Research Contracts on packaging materials placed by represented departments. These included work on cushioning materials being carried out by PATRA on behalf of D.M.X.R.D. and work by Microcell on ad hoc problems in connection with packaging materials being carried out for D.A.Arm.
1.2 Inter-Service Packaging Materials Specifications Working Party	Framing of new specifications and revision of existing specifications as necessary		3 B	D.M.X.R.D. D.Mat.R.D. and Inspectorates.	It has been decided to disband this semi-official Working Party which has met under the chairmanship of D.M.X.R.D.(M.X.5) in view of the recent setting up of a new Working Party under the Packaging Publications Sub-Committee of the I.P.T.S.-C. to undertake the preparation of DEF specifications for packaging materials.
2 Barrier Materials					
2.1 Development of Improved Bag Liners	Development of liners with better performance at extremes of temperature and better mould resistance EMR. 6/Paper/2685	W.O.P.S. 100 D.P.L. No. MX 15	3 B	D.M.X.R.D. Export Packing Services.	The wooden cases fitted with p.v.c. bag liners designed and formulated for improved low temperature performance have been returned to this country after exposure and handling trials at Fort Churchill. The modified p.v.c. liners were still unsatisfactory under arctic conditions and such liners, despite their excellent behaviour in temperate and tropical climates, cannot therefore be recommended for Service use.

					The value of polythene-coated kraft paper as a material from which bag liners can be made is being examined under an E.M.R. contract placed with Export Packing. No report on their work has yet been received.
2.2 **Behaviour of Barrier Materials Under Different Climatic Conditions**	Ability of packaging materials to meet the requirements of W.O.P.S. 100	D.P.L. No. MX 15	3 B	Materials Laboratory, Waltham Abbey.	No reports have yet been received from the Waltham Abbey laboratories.
2.3 **Behaviour of Hot-Dip, Strippable Coating under Low Temperature Conditions**		W,O.P.S. 100	3 B	D.M.X.R.D. and Fort Churchill	The two cases of machine tool spares preserved with hot-dip, strippable coating have now been examined after return from Fort Churchill. Some of the items were stripped at Fort Churchill and it was reported that there was no difficulty in removing the coating at low temperatures.
3 **Cushioning Materials**	The determination of the properties of the cushioning materials used in Service packaging under shock loading conditions at various temperatures and humidities EMR. 7/Pkg/76	W.O.P.S. 100 D.P.L. No. MX 15	2 C	PATRA	Work under the E.M.R. contract placed with PATRA continues. A large number of samples has been examined and measurements made. The second Progress Report covering the work up to July, 1955, gives results for the behaviour of coir pads. Work in comparing woodwool with sisal butt fibre has been completed. It is concluded, from figures showing the deceleration of a hammer dropped from varying heights on to 6" and 3" pads of both materials, that sisal butt fibre used at a density of 6 lb. per cu. ft. is equivalent in cushioning properties to woodwool at 5 lb. per cu. ft.

PACKAGING MATERIALS (Contd.)					
4 **Desiccants, Adhesive Tapes, Closures, etc.**					
4.1 **The Development of a Packaging Desiccant Cheaper and More Efficient than Silica Gel**	(a) Quicklime as a packaging desiccant	W.O.P.S. 100	3 B	D.M.X.R.D.	A note on the development work which has been carried out on the use of quicklime in packaging has been sent to G.5 and to the Services Packaging Organisations. A suitable type of container has also been recommended.
	(b) Examination of two French activated clays, "Dydragel" and "Cecacite F"		3 B	D.M.X.R.D. Crossfields	The full assessment of these materials involves the determination of their absorptive capacity at varying temperatures. A method for obtaining this information is being worked out by Crossfields for silica gel.
	(c) Control of quality of silica gel in depots				Consideration of methods for checking the quality of silica gel stocks in Ordnance Depots by weighing sample bags has been abandoned as impracticable.
4.2 **Protection of Labels on Packages**		W.O.P.S. 100	3 B	D.M.X.R.D. C.I.	The modified nitrocellulose lacquer to replace C.S.2184 has been approved after user trials and D.C.I. has been asked to prepare a specification.
5 **Performance and Evaluation of Packages**					
5.1 **Improvement of Service Packaging**	Vacuum packing process	W.O.P.S. 100	3 B	D.M.X.R.D. and Industry	Further work on the adoption of this form of pack awaits the commercial development of suitable barrier laiminates. Robinsons of Bristol are no longer supplying metal foil laminates suitable for use with the vacuum packing machine,

						but it is known that attempts are being made to produce a cellophane/polythene laminate which may be acceptable. Until alternative barriers are available no further work on this project is likely.
5.2	Improvement of Ammunition Packaging	Conditioning of cellulosic liners. (T.P. Process)	W.O.P.S. (Joint Service Research and Development Committee on Packaging Materials)	2	B	Materials Laboratory, Waltham Abbey R.O.F. Chorley and Industry.	Examination of liners at a number of manufacturers' works reveals a weight variation of about 1.5%, thus precluding weight measurement as a production-scale check on moisture content. The use of a 'Kappa' moisture meter has been suggested to D.I.Arm. The average moisture content of liners immediately after manufacture was high (12 to 13%).
5.3	Alternatives to Ethyl-Cellulose for Beakers for Guided Weapons	EMR. 6/Plas/362	Restrictive Coatings Committee	3	B	D.M.X.R.D., E.R.D.E., British Celanese.	British Celanese Ltd. can now produce flake with 36 - 38% acetyl value almost as easily as flake with an acetyl value of over 40%. Figures from E.R.D.E. indicated that this low acetyl acetate might be acceptable as a restrictive coating material. Celanese were therefore asked to produce a batch of flake of about 38% acetyl value and to extrude it into tubing using selected plasticisers. The production of these tubes presented no serious problems and they can be applied to charges by the stress relief method. It is expected that trials on rockets made with these tubes will be reported shortly. The Plastic Q Panel, set up by the Restrictive Coatings Committee, have reported that, in their opinion, Plastic Q should be replaced by a material having either an ethyl cellulose or a low acetyl acetate base - except for use on the 3" rocket charge which is now obsolescent.

V PLASTICS

1 Armaments

1.1 Ammunition

30 mm. Aden	Break-up shot	D.A.Arm. Authority No.J.18 Serial No. 115	2 B	A.R.D.E., Fort Halstead	Limited firing trials with certain low strength phenolics have indicated that such materials are too shock sensitive and disintegrate before leaving the barrel of the gun. Further trials using a very short barrel and photographic recording are being arranged. Other materials are being considered. The experimental work with loaded polyester resins has been deferred.
120 mm. B.A.T.	Break-up shot or shot made from a ballistically poor material	(W.O. No. A.2703)	3 B	A.R.D.E., Fort Halstead. D.Amm.P.	Present effort is being directed towards the use of a shock resistant material to a design which, it is expected, will result in a poor ballistic performance. Trials will be arranged.
3.7 in. Mk. 6	Igniter tubes of reduced water-vapour permeability	(W.O. Nos.A.4505) A.4701)	2 B	A.R.D.E., Fort Halstead.	Tubes made by the spiral winding of cellulose nitrate strip have been prepared. As an alternative tubes have been made using similar material but with a longitudinal lap joint. The results of firing trials are awaited.
V.T. Fuze	Nosecap failures	(W.O. No. A.4810)	1 B	A.R.D.E., Fort Halstead. Materials Laboratory, Waltham Abbey. McMurdo Instruments. E.M.I. Marston Excelsior.	Some fairly regular variations in density have been found, between different parts of PTFE nosecaps, using a technique in which the material was kept below the transition range of temperature (18-30°C.) throughout. The variation is, however, only about 0.2 per cent, and it is not known whether it has any connection with failures in functioning. Other properties of the material are being examined.

					Melting points and mechanical softening points of two commercial forms of Kel-F used for nosecaps have been found not to differ significantly; they are in the range 215-220°C.
Driving Bands	Improved non-metallic driving bands EMR's 6/Plas/400 6/Proj/3139 6/Proj/4678	(W.O. A.2508 A.2700 A.2711 A.2735 A.4505 A.4701 etc.)	1 A	A.R.D.E., Woolwich and Fort Halstead. Materials Laboratory Waltham Abbey. Halex, British Resin Products. Vulcanised Fibre	The long-term storage trials of standard test-pieces of nylons (types 6.6, 6.10, 6 and 11) in various grades continue. A comparison of the effects of storage at 60°C. and 100 per cent R.H. in the presence and absence of oxygen has confirmed the view that oxidation is a primary factor in embrittlement. The discovery that the embrittlement can be inhibited by preliminary steeping of the moulded nylon articles in certain liquids which combine the properties of antioxidants and plasticizers, has been followed up. Aniline, m-nitraniline, benzidine, methyl aniline, diphenylamine, alpha-naphthylamine, and phenyl beta-naphthylamine have all been found to be effective, especially the first three. Diphenylamine and phenyl beta-naphthylamine have been successfully introduced by adding them at the moulding stage, instead of steeping; but the technical difficulties of this process have not yet all been overcome. 105 mm. and 120 mm. bands, moulded from nylons 6.6 (ordinary and plasticized) and 6, were passed to A.R.D.E. for firing

V **PLASTICS** (Contd.)					trials, some of which have now taken place. Further moulded-to-size bands have been obtained from British Resin Products, composed of nylon cord impregnated with Hycar-modified phenolic resin. Bands made from both nylon and Terylene preforms, bonded with polyester resins, have been prepared; their heat distortion temperatures, and the conditions necessary for machining them, have been investigated; and they have been passed to P. and E.E. for firing trials which have commenced. Equipment is being constructed for mechanical testing of composite bands of this type.
Components Containing Celluloid	Examination of "Firmoid"	[A.2505, A.3523]	2 B	Materials Laboratory, Waltham Abbey.	Comparative ageing trials of celluloid and "Firmoid" (a solvent-deposited celluloid) in contact with WM propellant indicate a broad similarity in behaviour of the two materials. Both absorb similar amounts of nitroglycerine and lose similar amounts of camphor. Both become more flexible in consequence of the relatively greater plasticising effect of the nitroglycerine. Exposure of the two materials to dry conditions at 70°C, by themselves, shows that "Firmoid", which is initially less flexible than celluloid, fails, in 27 days, a bend test that celluloid can pass after 200 days.
Plastics and Rubber Components, Various	Effect of double base propellant on plastics and rubber materials		3 B	Materials Laboratory, Waltham Abbey.	A report is in draft.

1.2 Ordnance	Gun erosion: containers for "smears"		2 B	Materials Laboratory, Waltham Abbey.	Storage trials at ambient temperature of thermoplastics films under a 4 ft. head of Silicone Fluid M.200 have been abandoned after being in progress for two months. "Pliofilm" appears to be more resistant than three polythene variants (two of "Alkathene 7", with differing degrees of orientation, and the other an "Alkathene 2"/P.I.B. mixture), which are themselves no better than "Supronyl" (a nylon film) and cellophane. Another trial at 120°F confirms, after three months, that "Pliofilm" is better than the polythene variants and "Supronyl", and that cellophane gives relatively improved results. A trial at 140°F has been started.
	Gun barrel "burnishers": low friction materials			R.O.F. Woolwich.	Difficulty has arisen with the "burnishers" which are used in the boring operations of gun barrels. The boring tool is carried in a boring head which is, in turn, supported and centralised in the preliminary bore by the "burnishers" which consist of inserted pieces of material. In the past *lignum vitae* has been used for the inserts and one cause of the present difficulties might be due to the deterioration in quality of this natural product. Other contributory factors are thought to be increase in the boring rate made possible by tungsten-carbide tools and a change to soluble cutting oil as a coolant and lubricant. A range of plastics and other low friction materials is being considered as possible alternatives.

V **PLASTICS** (Contd.)					
Anti-Personnel	Light, non-metallic (non-detectable), mine	(W.O. Nos. EA 14a, EA 15a, EA 39b)	1	B	A.R.D.E., Langhurst.	It has not been possible satisfactorily to repeat the coating of diaphragms with p.t.f.e. and it is not proposed to continue the experiments.
	Plastic diaphragm striker EMR. 6/Plas/488	(W.O. Nos. EA 12c, EA 44)	1	B	Airscrew Co. & Jicwood. A.R.D.E., Langhurst. D.W.R.(D). M.E.X.E.	It appears from the contractor's report that it is not possible to construct a diaphragm in a plastics material, which has all the characteristics demanded by M.E.X.E. and A.R.D.E.
1.4 **Rocket Applications**						
Rocket-Motor Containers, etc.	Effect of single and double base propellant on glass fibre/polyester resin laminates	(W.O. No. A 5065)	3	B	Materials Laboratory, Waltham Abbey.	A six months exposure trial (Trial ADR/D2C/25A/6) of a glass-fibre/polyester resin laminate made by Saro Laminated Wood Products has been completed and a report will shortly be issued. The material has been in contact with single and double base propellants at 140°F.
	Effect of plastic and colloidal propellants on polystyrene		3	B	"	Storage trials for six months at 140°F of polystyrene in contact with colloidal (double-base) and plastic propellants have shown that this material has adequate resistance to these propellants and can be used, if otherwise suitable, in certain rocket motor assemblies. A similar trial of rubber-modified polystyrene has been arranged. The modified polystyrene has certain other desirable properties e.g. convenience of fabrication and higher impact strength, which make it an attractive material for the same and analogous purposes if the resistance to propellants is adequate.

2 **Chemical Defence and Flame Warfare**					
2.1 Chemical Defence	Development of a container for special fluids	(W.O. Nos. A/CD302 A/CD303)	2 B	C.D.E.E.	The moulding tools have been modified in accordance with a design change which provides for an increase of the cementing area. A number of mouldings has been produced which will be assembled, filled and submitted to trials.
3 **Clothing and Personal Equipment, General Stores**					
3.2 Personal Equipment	Development of a light-weight protective helmet	(W.O.Ref.1033 GS.445(b))	1 B	Durasteel.	A decision has not yet been reached by the Working Party on the method of test, consequently the proposed EMR has not yet been placed.
3.3 General Stores $4\frac{1}{2}$ Gallon POL Container	Development of a non-metallic jerrican EMR. 6/Plas/589	(W.O.Ref. 188 ES.9010(a))	2 B	D.E.S. Microcell	It is hoped to commence early in 1956 the construction of a prototype model as the design studies are now almost complete.
4 **Electrical, Electronics, Radar and Radio**					
High Temperature Dielectric Material	The co-polymerization of vinyl carbazole EMR. 6/Plas/684		B B	British Oxy-Gen Co.	The first progress report has been received. A number of problems concerning the straight polymer has been investigated before proceeding to work on the co-polymer aspects.
	Co-polymerization of acenaphthylene and isobutylene EMR. 7/Gen/1371		B B	Coal Tar Research Association.	A small-scale continuous-process plant has been built capable of making enough acenaphthylene monomer for the needs of the later development work.

V **PLASTICS** (Contd.)					
	Polyphenyl and polybenzyl polymers		B B	Materials Laboratory, Waltham Abbey.	With the purpose of synthesizing linear polymers of the polyphenyl and polybenzyl types, the following monomers have been prepared: (i) 1:4 dimethyl 2-chloromethyl benzene; (ii) 1:4 dimethyl 2:6 di(chloromethyl) benzene; (iii) 1-chloromethyl 2:3:5:6 tetramethyl benzene; (iv) 1:4 di(chloromethyl) 2:3:5:6 tetramethyl benzene. Of these, (i) and (iii) are to be treated with Friedel-Craft catalysts, and (ii) and (iv) are to be treated with sodium in a Wurtz reaction. [Products from the reaction of sodium-potassium alloy with p-dichloro-benzene and m-dichlorobenzene are being examined]. The monomer 2:5 difluorostyrene has been obtained by a synthesis from m-toluidine. Its polymerization is to be investigated.
4.3 Wave Guides	Dimensionally stable material for formers		- B	R.R.E.	The process of making the wave guide consists of the electrodeposition of copper approximately 1/16" thick on to a former which is subsequently removed by the action of a suitable solvent. Internal sizes and contours of the wave guide are important and must be exact and for this reason the material used for the formers is required to be dimensionally stable during the operational period and temperature range. Trial formers have been machined from polystyrene blocks but have proved unsatisfactory because of severe crazing which developed during the machining operation. A casting material is preferred as it would involve working

					only one master pattern or mould and would thus eliminate expensive precision machining for each individual former. Several dozen formers are required and the total machining load, if all had to be dealt with, would be unworkable. An investigation of materials is being carried out.
	Protective covering of low thermal coefficient of expansion		B	R.R.E.	A protective covering is required for a type of wave guide made by electro-depositing copper on to a stainless steel former. The design of the former provides for a system of mitred joints so that the assembly may be withdrawn from the copper shell after completion of the plating process. The copper wave guide thus formed is 0.010" thick and, because of its fragility, the protective covering is required also to serve as a reinforcement. Good adhesion of the two materials is essential and it is desirable that their coefficients of thermal expansion be approximately the same. The possibility of using glass fabric with a suitable bonding resin is being examined.
6 **Materials (including new polymers) and Properties**					
Polymer Properties	Water absorption of plastics		B B	Materials Laboratory, Waltham Abbey.	The study of the water absorption, from liquid water, by moulded discs of nylons 6.6, 6.10, 6, 11, and 'DB' has been completed, and changes in density of these materials when stored in sealed containers, subsequently to their removal from the water, have been determined. Isotherms for the absorption of water

				at 40°C have been obtained for nylon 6.6 in three physical conditions: powder obtained by precipitation from formic acid solution, moulding chips, and filings from a moulding. There are considerable differences between the isotherms, and an attempt is being made to find out whether this is due to differences in the crystallinity of the materials.
				Work has been completed on the water absorption of laminated tubes made of paper impregnated with resins; a report is being prepared.
Tensile properties		B B	Materials Laboratory, Waltham Abbey.	A Baldwin P.T.E. tensile tester has been installed in the laboratory and has been calibrated. A machine, based on a design of Bryce Maxwell, of Princeton University, for tensile testing of plastics at strain rates up to several hundred inches per second, has been installed in the laboratory. Nylon 6.6 specimens of 1 inch test length have undergone brittle fracture at 300 in. per second, at ambient temperature, but "Akulon M2A" (a polycaprolactam) still shows signs of ductility under these conditions. Unfortunately the spindle of the machine has undergone slight damage, and it is being repaired, with some modifications which it is hoped will permit a strain rate of 1,000 in. per second.
Stress relaxation		B B	"	Drawings of a machine for measuring stress-relaxation in flexure are complete. Analysis of some measurements in tension, on six different nylons, indicates that the

					initial rapid stress-relaxation is nearly linear with the logarithm of time; but this relationship breaks down after some 15 per cent of the stress has relaxed.
9 General					
9.3 Committees					
Joint Services Materials (Non-Metallic) Advisory Board - Research and Development Committee on Plastics	Sub-Committee No. 1 (jointly with British Plastics Federation) - Behaviour of plastics under tropical conditions			T.T.E., Nigeria.	The Sub-Committee has held two further meetings and has discussed reports on laminated sheet and tube, uncoloured "Perspex", and polystyrene mouldings. The exposure schedule for polythene protected with carbon black has been approved and arrangements made for supplies of materials. Two further reports, "Aminoplastic Mouldings" and "Phenolic Mouldings", are being printed.

VI RUBBERS					
1 Armaments					
1.1 Ammunition					
Propellants	Polymers as binders for propellants			E.R.D.E.	Samples of anti-crystallising rubber have been supplied to E.R.D.E. for test, and a sample of 2:vinyl-pyridine for polymerisation work. Further samples of the latter are being arranged.
Driving Bands	Improved non-metallic driving bands: Ebonites	(W.O. Nos. A2700 A2711 A2735)	C	Siemens Bros. E.R.D.E. A.R.D.E.	Impact Strength and Compressive Strength of several ebonites, prepared by Siemens, have been measured for comparison with results of firing trials; cross-breaking strength and heat-distortion temperature are under investigation.
	EMR. 6/Clo/23456	(W.O. Nos. A.2737 A.4005 A.4701)		Research Association of British Rubber Manufacturers.	
	EMR.7/Exptl/672	ditto	B	National College of Rubber Technology.	Various ebonites have been prepared and are being examined.
Cartridge Cases	Investigation of staining occurring during cleaning		3 B	R.O.F. Birtley. C.I.	No effect has been found which can be attributed to the rubber lining and it is considered that the problem is a metallurgical one.
Plastics and Rubber Components, Various	Specification for an explosive compatible butyl rubber			Materials Laboratory, Waltham Abbey.	A programme of compatibility testing in which a suitable selection of tests can be applied first to butyl polymers themselves, then to simple basic mixes, and

					finally to full technical mixes, has been proposed to E.R.D.E., as a means of ascertaining why all butyl mixes examined to date have shown adverse results on Silver Vessel (compatibility) tests (though not necessarily on 80°C. Stability tests also).
1.2 Ordnance					
Gun Barrels	Rubber tampions	O.B.Proc. 37,283	3 B	T.T.E., Nigeria. War Office, Singapore and Donnington.	Barrels stored at Lagos Beach, Nigeria, under corrosive conditions, were satisfactory after ten months' exposure and no further change has been reported in the condition of the rubber.
1.3 Mines					
Anti-Tank Mk. 7	Protective covers	(W.O. No. EA.12a)	2 B	T.T.E., Nigeria.	The results of Arctic trials are similar to those reported previously for tropical trials, showing moulded rubber to be the most suitable material.
Anti-Tank, Light	" "	(W.O. No.EA.13a)	2 B	M.E.X.E.	Modifications to the mine body to improve corrosion resistance have affected the adhesion of the rubber to the metal. A method which gives a satisfactory bond has been developed and is being tried on a larger scale. The Arctic trials using anti-crystallising rubber have been deferred until completion of this work.
1.4 Rocket Applications					
Rocket Motors	Tube liners with low heat transfer properties	(W.O. No. A.5065)	2 C	A.R.D.E., Woolwich. R.A.E.R.M.	Laboratory examination of the rubber compounds has not yet been completed.

VI RUBBERS (Contd.)					
5 Engineers' Equipment					
Fuel Tanks	Development of collapsible 10,000 gallon tank	(W.O. No. Eh1)	1 B	Dunlop Rubber Co. C.I.	Arctic trials on the first prototype tank have been satisfactorily completed. Examination of the tank on return to U.K. showed that its condition was very good and it is now in use by the Army for training purposes. The second prototype failed at one seam during tropical trials. No explanation of the failure could be given after examination on return to U.K. and laboratory tests of seams are to be carried out. Evaluation of proofed fabrics designed to give an increased safety factor is about to commence.
	Development of collapsible 30,000 gallon tank	(W.O. No. Eh2)	1 B	Dunlop Rubber Co. C.I. M.E.X.E. D.R.E.E.	Two prototype tanks have been made using a modified lightweight fabric to improve adhesion. Filling and emptying tests using water have been completed satisfactorily and it is hoped shortly to begin fuel tests. In connection with the testing of both 10,000 gallon and 30,000 gallon tanks, bunds of P.V.C. sheeting (supported by sand-bags) are being designed to prevent loss of fuel in case of accidental damage to the tanks.
	Development of 1,000 ton tank			M.E.X.E. D.R.E.E.	A design study of a container to hold approximately 1,000 tons of fuel is being carried out.

Airfield Membranes	Waterproof membranes resistant to jet engine fuels and jet blast	(W.O. No. ER4a)	2 C	M.E.X.E. D.R.E.E.	Air Ministry has been asked to assess the heat resistance.
6 Materials (including new polymers) and Properties					
New Polymers	Evaluation for Service applications EMR. 294/2/355		B B	R.A.B.R.M. Materials Laboratory, Waltham Abbey.	Further reports have been issued on the evaluation of Kel-F Elastomer, Poly-FBA, Sulphur Vulcanisable Silicone Rubber, Resin-Rubbers and Poly-Urethane Rubbers. Further work on the chemical and heat resistance properties of the newer polymers is in progress. Tests of the insulation resistance of Kel-F Elastomer have shown that this polymer may be of interest as a dielectric material at temperatures up to 200°C. Kel-F Elastomer and polythene have been found to be superior to Hypalon and butyl rubber in resistance to red fuming nitric acid. The Kel-F Elastomer retains its elasticity but polythene becomes brittle; the cause of this is being investigated. 50, Chemigum SL, Hypalon, Acrylon BA-12 and EA 5, Hycar PA and PA 21, Philprene VP 15 and VP 25, Elastomer W96 and Thiokol ST are under examination and some have already been reported upon.
Natural Rubber	Anti-crystallising rubber			British Rubber Producers Research Association.	See page 3

VI RUBBERS (Contd.)				
Polymer Properties	Dynamic properties EMR. 294/2/355	B	R.A.B.R.M. D.M.X.R.D.	The co-operative research mentioned in the previous report is not yet completed.
	Rubber/textile adhesion EMR. 294/2/355	B B	R.A.B.R.M.	Proofing of the fabrics specially woven to investigate the effect of weave and area of fabric in contact with rubber has been completed and examination of bond strengths has commenced. Arising from earlier work, it is now shown that high bond strengths between rubber and terylene tyre cord can be obtained by suitable treatment of the cord. The results are only slightly inferior to those obtained using isocyanates; the treatment is carried out in aqueous solution, which is more acceptable in commercial practice. Further development work is planned.
	Rubber/brass bonding EMR. 7/Exptl/672		D.M.X.R.D. and National College of Rubber Technology	A zincate electrode for the brass plating bath has been found to be unsatisfactory, and a mercury-mercuric oxide electrode is being prepared instead.
	Stress relaxation EMR. 294/2/355	B C	R.A.B.R.M.	This work has been held up by shortage of staff.
	Swelling of rubbers by esters		Materials Laboratory, Waltham Abbey.	A report is in draft.

	Behaviour under tropical and arctic exposure:				
	Silicone rubbers	W.O.P.S.100	B B	T.T.E. Nigeria. D.R.B., Canada.	Not yet started.
	Rubbers to Service Specifications	W.O.P.S.100	B C	T.T.E. Nigeria. D.R.B., Canada.	
	Compression set				It has been found, with both natural rubber and acrylonitrile rubber vulcanizates, that the compression set obtained with two pieces of rubber pressed together is greater than that with a single piece of double thickness.
	Internal pressure				Apparatus for measurement of internal pressures of solvents and elastomers is being constructed.
Antiozonants	Evaluation of materials claimed to prevent ozone degradation of material and synthetic rubbers		B B	Research Assocns. E.R.D.E.	Static and dynamic outdoor exposure tests have shown that antiozonants, of U.S. origin, have a marked effect in reducing the degradation of natural and nitrile rubbers. Further tests in ozone cabinets with controlled amounts of ozone will commence shortly.
Plasticisers	Evaluation of plasticizers for nitrile rubbers for low temperature use	W.O.P.S.100	B B	R.A.B.R.M.	The second programme has not yet been completed.

VI RUBBERS (Contd.)			
7 Specifications, Standardization and Test Methods	Silicone Rubbers		Agreement has not yet been reached with the material suppliers on the level of properties to be specified.
	Compatibility of rubbers with a castor oil-based hydraulic fluid	Materials Laboratory, Waltham Abbey.	The work has been concluded and a report is in draft.
	Miscellaneous problems	Materials Laboratory, Waltham Abbey.	The failure of certain driving bushes has been found to be due to the use of different elastomers in the same flexible connection.
		D.M.X.R.D.	Some dust covers for gear levers, which had been found to age severely, were shown to be made of nitrile rubber, not neoprene as supposed.
			The elastomer used in some collapsible fuel funnels has been identified as a nitrile rubber similar to that specified as A3 in DEF8. (D.C.I. has confirmed this and prepared a specification).
			Failures in bump stops, in which rubber is bonded to brass, have been investigated. Both cohesive and adhesive failures have occurred. A report is being prepared.
			The use of poly-urethane rubbers in place of natural rubber for tank track pads is being investigated.
9 General 9.2 Advice to other Government Departments	Special rubbers	A.E.R.E., Harwell	Rubbers with high brightness value are required for special applications. Samples are being made up using crepe rubber heavily loaded with titanium dioxide of both rutile and anatase types to assess the suitability for these applications.

	Rubber bags			A.W.R.E., Aldermaston	Methods of making special rubber bags have been suggested.
9.3 Committees	B.S.I. Committee RUC/-/1 Standardisation of methods of test				The sixth meeting of I.S.O. TC/45 - Rubber was held in Dusseldorf in September, 1955. Seventeen methods of test have been approved as "Draft I.S.O. Recommendations". Work is continuing on further methods.
	B.S.I. Committee RUC/15 and I.S.O. TC.45 (Working Group 6) - Classification of rubber vulcanisates by physical properties				Modifications have been made on TC.45 level in the list of properties which will be specified and some guidance obtained on the levels to be quoted. This necessitates a revision of the draft tables prepared earlier.

VII ADHESIVES, SEALING COMPOSITIONS AND VARNISHES					
1 Adhesives	(a) Development of metal/metal adhesives compatible with explosives	(A.5064)	3 B	Materials Laboratory, Waltham Abbey.	*
	(b) Tensile strength of joints	(W.O. No.A.5064)	3 D	Materials Laboratory, Waltham Abbey.	*
2 Adhesion	(a) Determination of the heats of wetting of adhesives EMR. 7/Chem/176		B A	Nottingham University.	The surface area of supplies of aluminium powder has been evaluated and the heat of wetting by benzene has been ascertained.
	(b) The mechanism of adhesion of clean solids and the effect of surface films EMR. 7/Exptl/648		C A	Cambridge University.	It has been shown that complete adhesion occurs between clean metals, provided that the metal is heated to a temperature at which annealing can occur. These experiments have been carried out with metals such as copper and silver, where the annealing temperature is comparatively low. The adhesion and interaction of refractory metals and non metals is being studied. This involves the development of special high temperature furnaces which are now complete. In addition the adhesion and interaction between molecularly flat surfaces is being investigated. Methods for preparing these surfaces in contact have been worked out and it has been found that adhesion at room temperature is very high. The influence of surface films is being investigated.

	(c) The photo-elastic examination of stress distribution in joints EMR. 7/Exptl/681 EMR. 7/Gen/1327		B A	University College of North Staffordshire. Royal Technical College Glasgow.	The stress distribution in an 'Araldite' joint between steel adherends has been examined in order to establish the correct technique. Joints have been made where the modulus of the adherend is one twentieth of that of the adhesive. The effect of variation of design of these joints is now being examined.
	(d) The napkin-ring method of testing adhesives EMR. 7/Exptl/558		B A	Nottingham University.	This investigation has been transferred to Nottingham University. The student who is working on this problem has examined the installation at Kings College, arranged its transfer to Nottingham and is rebuilding it.
	(e) The examination of the behaviour of compounds containing hydroxyl groups on oxide surfaces EMR. 7/Gen/1361		B A	Queens University, Belfast.	The apparatus has been assembled and trial runs have been made.
3 Sealing Compositions					
Thread-sealing Cements for Ammunition	(a) The strength of cemented threaded joints		2 B	Materials Laboratory, Waltham Abbey.	Work continues on the effects of thread dimensions and profile on the failing torque of cemented joints. The modulus of elasticity of the cement appears important in affecting the load distribution. The degree of load concentration is being determined for a number of cements ranging from brittle to highly flexible.
	(b) The sealing efficiency of cements	W.O.P.S.100 O.B.Proc. No.37,799	2 B	Materials Laboratory, Waltham Abbey.	Comparative trials of 25 cements, including all those used in Service for threaded joints in ammunition, have been completed. All those containing solvent set slowly

VII **ADHESIVES, SEALING COMPOSITIONS AND VARNISHES** (Contd.)					and are mostly weak. 10 out of 12 of these failed in some degree to seal a standard threaded assembly. In contrast, chemically setting cements (not containing solvent) set faster, are generally stronger, and (with one or two possible exceptions out of 13) satisfactorily seal threaded joints. A report is in draft.
	(c) The development of an improved stiff luting or crevice filler	C.I.N.O. W.O.P.S.100 O.B.Proc. No.37,904	3 B	Materials Laboratory, Waltham Abbey.	R.D.1284A has been developed and has been shown to be superior to Lutings Mk.4, Mk.6 and Optical cement No.1 Mk.1 The replacement of the latter compositions by R.D.1284A has been recommended. R.D.1284A is already used in an interrupted burning rate apparatus (E.R.D.E.) and its Service use for filling crevices in depth-charges (in place of R.D.1158G) is contemplated. Large-scale manufacture is being arranged. A specification has been drafted and a report is being prepared.
	(d) The development of an improved chemically setting cement	W.O.P.S.100 O.B.Proc. No.37,799	2 B	Materials Laboratory, Waltham Abbey.	See page 4
4 **Varnishes**					
4.1 **Ammunition**	(a) Replacements for R.D.1177		3 B	Materials Laboratory, Waltham Abbey.	Cyclopentadiene treated linseed oil/ phenolic resin varnishes have given good results in exposure trials. Their storage properties are good but their alkali resistance is slightly inferior to that of R.D.1177. In their other properties they are similar to R.D.1177.

				Epoxy resins esterified with oil fatty acids show good chemical resistance and drying properties but on exposure to weathering and humidity are not so good as R.D.1177. Epoxy/polyamide resin compositions were promising in exposure tests but have poor storage stability. Because of the alkalinity of the polyamide resins it is doubtful if these can be made compatible with explosives. Chemical resistance of air-dried films is exceptionally good. Acceptable alternatives to R.D.1177 are at present limited to approved alternative phenolic resins in combination with tung-oil. Vinylite based varnishes are also under consideration.
(b) Protection of internal surfaces of ammunition		2 B	Materials Laboratory, Waltham Abbey.	Tests of bituminous varnish R.D.1270 on phosphated steel have shown that this material gives the best protection under humidity condensation conditions (as might be experienced by empty components in storage). Phenolic resin/tung oil varnishes, however, are better on outdoor exposure.
(c) Improved detonator varnishes		2 B	Materials Laboratory, Waltham Abbey. R.O.F. Chorley.	Epoxy/coumarone based varnishes, for external and internal varnishing of detonator shells are under trial at R.O.F. Chorley in collaboration with A.R.D.E. Chorley. Climatic trials will follow if application trials are successful. The possibility of proceeding further with the vinylite based mouth-sealing varnish (alternative to R.D.1177) is still under discussion with A.R.D.E. Chorley. Present indications are that the performance is inadequate.

VII ADHESIVES, SEALING COMPOSITIONS AND VARNISHES (Contd.)	(d) Dyestuffs	2 B	Materials Laboratory, Waltham Abbey.	Fifteen of the dyestuffs examined to date have been selected as suitable for colouring five types of lacquer in six distinctive colours, for application to aluminium, copper, brass and tinplate surfaces. Storage trials are in progress. The use of these dyestuffs in ammunition varnishes will depend on compatibility clearance by E.R.D.E.
4.2 Electrical applications	Development of insulating varnishes resistant to high temperatures	2 B	Materials Laboratory, Waltham Abbey.	Preliminary tests are being made on a a number of varnishes prepared from commercially available oils and resins. Compositions include epoxy/phenolic, epoxy/polyamide, epoxy/fatty acid ester and, epoxy/melamine condensates. Behaviour on storage at elevated temperatures is being observed. Appearance and weight loss are being used as sorting criteria.

Note. There is no progress to report on the items marked *

VIII **ENGINE AND BURNER FUELS**					
1 **Standardization; Specifications; etc.**	Fuel Panel activities			Ministry of Defence	The need to revise the specification for normal grade (MT 70) gasoline has become apparent due to the poor performance of certain Service transport vehicles using this fuel. Discussions have taken place with the petroleum industry and the Ministry of Fuel and Power and a revised octane rating of 74 (Motor Method) is to be demanded. Reference fuels for gasoline and diesel engine acceptance tests have been agreed and a Defence specification is being published. Specifications for furnace fuel oils are under consideration.
2 **Fuels for Spark Ignition Engines**	(a) De-leading of gasoline to make it suitable for use in certain stationary engines, heating and lighting equipments EMR. 6/Stores/33606	(ES 8002)	3	British Petroleum Co. S.R.D.E. D.I.S.	See page 5
	(b) Examination of engine deposits from stationary engines run on high lead content gasoline EMR. 6/Engs/7946			D.C.I. Sondes Place Research Institute	X-ray diffraction techniques and chemica methods have been employed to examine engine deposits from engines using high lead content gasoline and lubricated wit various additive-type oils. Most of the analytical results are now available and a report will be issued.
3 **Fuels for Compression Ignition Engines**	Performance of spark ignition type fuels under compression ignition conditions	W.O.P.S. 71		Ricardo & Co.	In connection with the development of a "multifuel" engine by F.V.R.D.E. the combustion of various gasoline referenc fuels of different chemical types, but the same octane rating, is being studie under c.i. conditions.

ENGINE AND BURNER FUELS (Contd.)	Performance of diesel engines on various grades of fuel	W.O.P.S. 71	F.V.R.D.E.	The use of iso-propyl nitrate as a cetane number improver is being tested in a variety of gasoline type fuels.
Fuel Additives	Examination of de-icing compounds		F.V.R.D.E. British Petroleum Co.	A de-icing compound which will prevent icing troubles, when small quantities of water are present in fuels, is being examined to see if it is suitable for Service use. Clogging of fuel filters during Arctic operation is the main Service problem which might be alleviated by the use of these compounds.

IX LUBRICANTS AND HYDRAULIC FLUIDS					
1 General, Committees Standardization: Specifications, etc.	(a) Lubricants Working Panel of Joint Services Petroleum Products Sub-Committee of Engineering Standards Co-Ordinating Committee			Ministry of Defence	The items mentioned in the last progress report for July 1955 are still under review. Defence specifications for a transformer oil and a fuze lubricant are now being printed.
	(b) Gear oil and engine oil assessment; Advisory Panels to D.C.I.			D.M.	This work has continued. The water susceptibility of certain engine oil additives is to be examined. No information appears to be available on the behaviour of detergent engine oils to Spec. DEF-2101A under wet conditions such as exist in multi-stage air compressors.
	(c) Advisory work for F.V.R.D.E.	W.O.P.S. 1 W.O.P.S. 71 M.X.13	3	F.V.R.D.E.	The possibility that failures of fuel pump diaphragms may be caused by changes in gasoline composition is being considered. Rolls Royce have suggested that certain engine failures due to piston ring scoring are due to the quality of the Service engine oil. This pointis being explored and the firm is being asked for more specific information. Tests are in progress with a brake fluid which is claimed, after extensive vehicle trials in U.S., to be suitable for arctic and tropical use. The relative merits of oil and grease as chassis lubricants are being explored and vehicle trials are still in progress.

IX LUBRICANTS AND HYDRAULIC FLUIDS (Contd.)			
	(d) Research and Development Committee on Lubricants and Hydraulic Fluids		A first report on the Committee's activities has been published and will be considered by the Joint Services Materials (Non-metallic) Advisory Board. The last meeting of the Committee was held at the Mechanical Engineering Research Laboratory at East Kilbride.
	(e) Proposed Service trials on fuels and lubricants	D.M.X.R.D. F.V.R.D.E.	Representatives of D.M.X.R.D., and F.V.R.D.E. and a consultant from the London Transport Executive visited B.A.O.R. to investigate the possibility of carrying out trials of fuels and lubricants in the Army. A report is in preparation.
	(f) Handbook of Service Lubricants	D.M.X.R.D.	The fourth edition of the "Handbook of Service Lubricants and Temporary Protectives" has been published. A reprint will soon be necessary as 3,500 copies which were printed have nearly all been distributed.
	(g) B.S.I. Committees PTC/-, PTC/-/1, PTC/2, PTC/3, PTC/7/4		These B.S.I. Committees cover, Fuel Oil, Lubricating Greases, Lubricating Oils, International Standardization, and Penetrating Oils respectively, and are considering materials and specifications of Service interest.
	(h) Institute of Petroleum Committees Nos. ST-3, ST-4, ST-5-E, ST-6, ST-6-A, ST-6-C, ST-6-E, ST-6-G, ST-12, ST-12-C		These Institute of Petroleum Committees cover gasolines, fuel oils, lubricants, greases, protectives and specialities such as cutting oils. Members of the Co-ordinating Research Council have visited this country to give information on the working of that body in the U.S.

					and on the development there of a new engine for lubricant research and testing. The Protectives Panel of the Institute, for which D.M.X.R.D. provides the secretary, has written a paper, for early publication in the I.P. Journal, on the development of the "CRL Beaker" test method for solid-film protectives.
2	**Engine and Compressor Oils**	Development of an arctic grade of engine oil EMR. 6/Lub/544	W.O.P.S. 100	Monsanto	Work is continuing on this project which is aimed at producing, in this country, a suitable grade of arctic engine oil.
3	**Gear Lubricants**	(a) Evaluation of surface treatments for hypoid gears EMR. 6/Lub/543	W.O.P.S. 1	I.F.V. British Petroleum Co.	Lubrication of hypoid gears is normally achieved by additive-type lubricating oils. The possibility that surface treatment of hypoid gears might make the use of special lubricants unnecessary is being investigated. Treatments being studied include phosphating, the use of molybdenum disulphide and the "sulphinuz" process. Examination of high speed/low torque conditions and low speed/high torque conditions is now complete. A report will be prepared and the results discussed with the appropriate engineering branches. Further tests in equipment may follow.
		(b) Development of an arctic grade of hypoid oil		Anglamol	An EMR is being negotiated to determine, in the first place, the solubility of additives in possible base oils. Supplies of such an oil are required by F.V.R.D.E. for Arctic Trials in Canada during the winter of 1956/57.

X LUBRICANTS AND HYDRAULIC FLUIDS (Contd.)	(c) Basic research into the mechanism of gear failure EMR. 7/Exptl/487		M.E.R.L. (D.S.I.R.)	This work is continuing. A power-circulating hypoid axle rig is being installed at M.E.R.L. for correlation of results.
4 Hydraulic Oils and Brake Fluids	Development of wide temperature range brake fluid EMR. 7/Gen/1495		British Hydro-mechanics Research Association.	An EMR has been negotiated to cover a survey of equipment of possible use in testing brake fluids. New formulations will be evaluated later.
5 Instrument Lubricants	Use of OX-10 at high temperatures		O.B.	A complaint is being investigated that a clock mechanism lubricated with OX-10 stops when cooled to normal after being run at a high temperature. Contamination is suspected.
6 Gun Lubricants	Properties of intensifier fluid at low temperatures		C.I.	O.M.-750 has been found to be satisfactory at -15°F. for use as an intensifier fluid.
7 Machine Shop Lubricants	Advice to ordnance factories and other establishments		R.O.F's and other Establishments	R.E.M.E. Arborfield, A.W.R.E., Aldermaston and R.O.F. Woolwich have been visited for discussion of lubrication difficulties arising from workshop practice.

X TEMPORARY PROTECTIVES

1 Applications

(a) Ball bearings	W.O.P.S. 100	T.T.E. Nigeria. D.A.I. C.I.	Bearings will shortly be examined after twelve months shelf storage in T.T.E. and in this country. An interim report has been issued by D.A.I. and D.C.I. covering the first six months storage.
(c) Rifles	W.O.P.S. 100	D.I.Arm. C.I.	Packaged rifles subjected to six months base depot storage at Singapore followed by six months in the high temperature, high humidity chamber at Woolwich showed marked differences in condition. Boxes treated with "liquid envelope" were found to contain quantities of water; oil PX-4 was found to give sufficient protection in conjunction with a water-vapour proof barrier. IPPTS-C Small Arms Panel tests have demonstrated the inadequacy of rifle chests without internal fittings. A further prototype is to be tested in the near future.
(d) Tungsten carbide cores		D.G. of A.	Advice has been given on the best method of applying hot-dip strippable coatings to these heavy and valuable items.
(e) Air-raid sirens		Home Office.	Recommendations have been made for protecting sirens in exposed positions without interfering with their functioning.
(f) Laboratory equipment		University of Aberdeen	Advice has been given on preventing the corrosion of equipment in biological laboratories.
(g) Mechanical fuze parts		R.O.F. Blackburn C.I.	The use of methanol has been suggested to prevent spasmodic rusting thought to be due to perspiration residues. Lanolised oil PX-14 is being tried to stop the staining of brass parts.

TEMPORARY PROTECTIVES (Contd.)				
2 Improvement of Performance				
2.1 Petroleum Based Materials	Improvement of high temperature performance	W.O.P.S. 100	C.I.	Work on this problem is continuing.
2.2 Oil-Types	Use in engine preservation	W.O.P.S. 100	C.I. D.I.E.M.E. R.A.O.C. Pres. and Packing Organisation.	Engines have been specially protected with the oil-type protective PX-4 by I.E.M.E. and it is hoped to arrange low temperature starting tests within the next few months.
2.3 Hard-film Types	Tropical tests	W.O.P.S. 100	C.I.	Exposure for three years at T.T.E. of packages containing the three Service hard-film protectives has been completed. PX-2 (Spec. C.S. 1033E) and PX-9 (Spec. D.T.D.663) have been shown to give comparable protection and to be slightly inferior to PX-3 (Spec. DTD.279B).
2.4 Low Temperature Behaviour	Examination of all types under vibration at low temperature	W.O.P.S. 100	S.R.D.E. C.I. D.M.X.R.D.	Packages have been tested at -40°F. The protectives which suffered least from defects due to brittleness were those of a greasy nature such as LG-280 and PX-12. (Preservative for Metal Components containing Rubber). Some of these packages will be sent to T.T.E., together with controls, to determine whether their protective properties have been impaired.
2.5 Grease-like Types	Use of PX-12, Preservative for Metal Components containing Rubber	W.O.P.S. 100	C.I. Materials Laboratory, Waltham Abbey.	Laboratory tests are to determine the effect of the material on plated surfaces. The compatibility of this material with single- and double-base propellants has been established as it is being

					considered for use in a rubber pressing operation. The use of the material on propeller blades has been found to be detrimental because of attack on the adhesive of the de-icing sleeve.
3 Development of New Types; Introduction into Service Use	(a) Vapour phase inhibitors	W.O.P.S. 100		T.T.E., Nigeria. E.R.D.E.	Tests on packages containing these inhibitors are continuing. Further interim examination has confirmed previous findings of the susceptibility of zinc to corrosion by these materials.
	(b) Slushing compounds	W.O.P.S. 100		C.I.	Work on these materials in continuing.
	(c) Cold dip strippable coatings	W.O.P.S. 100		C.I. D.M.X.R.D.	Laboratory examination of proprietary materials is continuing. Because of possible use on medical supplies tests on silver and cadmium-plated surfaces will be included.
				T.T.E., Nigeria.	Storage at T.T.E. of packages containing parts protected with a number of proprietary materials has been concluded. None of the materials tested gives protection equal to that of the Service hard-film protectives.

XI TROPICAL TESTING					
1 Studies of Deterioration					
1.1 Metals; Methods of Protection	(a) Atmospheric pollution		B A	T.T.E., Nigeria.	Standard specimens of zinc and copper-bearing steel prepared by B.I.S.R.A. have been exposed at sites in Nigeria to determine their corrosion rates.
	(b) Fundamental studies on corrosion		B C	"	Effect of airborne salt, and under-water exposure, on corrosion. The latest results have been published in the Journal of Applied Chemistry, Sept. 1955.
	(c) Light alloys		C B	"	Specimens have now been on exposure for six months but a report is not expected for a further six months. The trial as originally planned has been extended by the simultaneous exposure of specimens in Canada and in Nigeria in order to compare the severities of conditions at these two sites.
	(d) Metal coated structural steel plates		C B	"	There has been no further change in the condition of these specimens.
	(e) Painted steel plates		B B	"	
	(f) Comprehensive trial of metal finishes on ferrous and non ferrous metals	W.O.P.S. 100		"	A report by T.T.E. on the behaviour of specimens is to be published shortly.
1.2 Non Metals	(a) Aminoplastic mouldings				
	(b) Phenolic mouldings				
	(c) Cellulose nitrate sheets				

(d) Nylon monofilaments				
(e) "Transpex II", an optical grade of polystyrene	W.O.P.S. 100	B C	T.T.E., Nigeria.	Items (a) - (h) Two years exposure has been completed; reports on their performance are in preparation.
(f) Expanded ebonite				
(g) Polyvinyl chloride covered cables				
(h) "Durestos" sheet and mouldings				
(i) Laminated sheet and tubing	W.O.P.S. 100	B B	"	The examination of results by collaborators from the industry has been completed and agreement has now been reached on certain controversial points. The report is now being prepared for publication.
(j) Uncoloured 'Perspex'	W.O.P.S. 100	B B	"	No change.
(k) Polyvinyl chloride	W.O.P.S. 100	B B	T.T.E., Nigeria. C.I.(Woolwich) Materials Laboratory, Waltham Abbey.	C.I. have completed their investigations and Materials Laboratory, Waltham Abbey are preparing a programme of tests to determine the chemical deterioration.
(l) Nylon mouldings	W.O.P.S. 100	A A	"	All specimens have now been taken off exposure and returned to C.I. for examination. There has been very little visual change in the specimens except that some 6:10 mouldings have turned grey at the desert site.

XI **TROPICAL TESTING** (Contd.)

(m) Polystyrene mouldings	W.O.P.S. 100	B	A	T.T.E., Nigeria.	Samples have been on exposure approximately twelve months. Those samples at the desert site are going yellow and are developing surface crazing. There is no evidence of insect attack. Those with high impact resistence are showing the greatest deterioration in electrical properties.
(n) Low pressure laminates	W.O.P.S. 100	B	A	"	The preparation of specimens and provision of test equipment are in hand.
(o) Protected polythene	W.O.P.S. 100	B	A	"	This trial is at the same stage of planning as (n) above. It is hoped to measure the accentricity of the conductor in polythene covered cable by X-ray photography.
(p) High softening point "Perspex"	W.O.P.S. 100	B	A	"	The results have been forwarded to the sponsors and on receipt of their evaluation of deterioration the report will be published.
(q) Transparent glass fibre reinforced polyester resins		C	B	"	The trial schedule has been agreed with the firm and with T.T.E. An estimate has been produced and the specimens are being prepared.
(r) Glass fibre laminate bridge decking materials		B	A	"	A report on a three years' exposure trial has been passed to M.E.X.E. Very little further deterioration has occurred.
(s) Behaviour of optical glasses in semi-sealed containers		B	A	"	B.S.I.R.A. have not completed their modification of the containers.

1.3 Textiles	(a) Actinic degradation of textile fibres	Recommendation of 4th Commonwealth Defence Conference on Clothing and General Stores	3	B	T.T.E., Nigeria C.I. (Didcot).	See I.1(b)
	(b) The comparative assessment of standard British and other processes of rot-proofing cotton	W.O.P.S. 100	3	B	D.M.X.R.D. T.T.E., Nigeria C.I. (Didcot) and various U.K. laboratories.	See I.5(a)
	(c) Rot-proofing of cordage	W.O.P.S. 100	3	B	D.M.X.R.D. T.T.E., Nigeria. A.I.D. C.I. and Industry	Exposure of sisal, manila and Italian hemp ropes proofed with "Copper 8" and copper naphthenate is continuing.
1.4 Timber	Identification of termites	W.O.P.S. 100	B	B	T.T.E., Nigeria	Identification of termite species and studies of their attack on timber are proceeding. Laboratory colonies of the drywood termite have been established.
1.5 Adhesives	(a) Aircraft assembly adhesives	W.O.P.S. 100	B	A	"	A report on the effect of four years exposure has been sent to the R.A.E.
	(b) Plywood assembly glues	W.O.P.S. 100	B	A	"	A report on the samples after three years exposure has been passed to the F.P.R.L. together with a number of failed samples for examination.
	(c) Adhesives for light alloys	W.O.P.S. 100	B	A	"	Samples withdrawn after two years exposure have been returned to the R.A.E. for examination.

XI TROPICAL TESTING (Contd.)					
1.6 Paints and Varnishes	(a) Paints incorporating fungicides	W.O.P.S. 100	B A	T.T.E., Nigeria.	Extensive rusting of the varnished panels has occurred and small corrosion blisters are present on all the painted panels.
	(b) War equipment paints	W.O.P.S. 100	B A	"	Little change apart from some general deterioration.
	(c) Ready mixed oil paints	W.O.P.S. 100	B A	"	Fading has continued at the hot dry site and discoloration has been noted at the hot wet site.
1.7 Photosensitive Materials	(a) Photographic film	W.O.P.S. 100	B A	"	Samples have been sent to the manufacturer for test after three months exposure.
	(b) Lithographic printing plates	W.O.P.S. 100	B A	"	The trial continues.
1.8 Electronic Components	(a) Radar components	W.O.P.S. 100	B A	"	The trial continues. The components in general are showing a steady deterioration.
	(b) Radome laminates	W.O.P.S. 100	B A	"	This trial is now completed but a final report is awaited from T.T.E. The effect of exposure was least on silicone rubbers S.50 and E.360 and greatest on Epikote 828 loaded with either mica or Sturge A.4.
1.9 Ammunition	(a) Metallised coatings on bombs	W.O.P.S. 100	B A	"	There is no change in the specimens generally except that moderate rusting is present on half the bombs at the marine site.
	(b) Gun ammunition	W.O.P.S. 100	B A	"	Many items are now rusted and the painted legends are indecipherable. There is no evidence however that the stores are unserviceable.

	(c) Ctges. QF. 20 pdr. APDS/T with nylon driving bands	W.O.P.S. 100	A	A	T.T.E., Nigeria	Firing trials after twelve months exposure to jungle and desert conditions show that neither the accuracy nor the functioning of the ammunition has been effected. Unboxed rounds are being returned after two years exposure for further firing trials and their general appearance shows some deterioration in the form of cracks and blow-holes in the centering bands. Boxed rounds at the two sites are being left on exposure for a total of four years.
	(d) Mines and components	W.O.P.S. 100	B	A	"	These components have now been on exposure now for one year and certain stores have been returned to U.K. for examination.
	(e) Packaging of gun barrels	W.O.P.S. 100	B	A	"	There is no further change in the condition of these gun barrels. The trial continues.
	(f) Mines AT Mk.V	(W.O. No.EA.40)	2	B	"	See VI 1.3.
1.10 Equipments and Instruments (other than those under 1.1 to 1.8)	(a) Engine air cleaners	W.O.P.S. 100	A	A	"	The trial has been completed and all items have been returned to F.V.R.D.E. for examination.
	(b) Gyro gunsights	W.O.P.S. 100	A	A	"	One standard gunsight and one tropicalised gunsight have been returned to the manufacturer for detailed examination after eighteen months exposure.
	(c) Standard storage boxes	W.O.P.S. 100	B	A	"	There is little change in the condition of boxes at the hot wet and marine sites but boxes buried at the hot dry sites show blistering and flaking of the paint.

XI **TROPICAL TESTING** (Contd.)					
	(d) Inflatable life rafts		B A	T.T.E., Nigeria	Storage trial continues.
	(e) Apparatus illuminating sights	(W.O. No.A.2123)	2 B	"	The equipment is now awaiting shipment to T.T.E.
2 **Trials on Behalf of Firms and Research Organisations**	Evaluations of the performance of commercial articles		C B	"	Trials of interior, exterior and anti-fouling paints continue. A large scale trial of fungicidal paint systems has been agreed with the sponsor and samples are awaited. Wood stakes treated with insecticides continue to be withdrawn at regular intervals for examination. It has not yet been possible to assess the relative effectiveness of the insecticides for prevention of termite attack. Treated books in crates at the hot dry site have been withdrawn and returned to the sponsor on account of heavy termite attack but those on open shelves remain in good condition. Bags of cement have been sent for trial but owing to damage to two bags in transit and flooding at the hot wet site exposure has not yet started; replacement samples have been despatched. A storage trial of various insecticides is planned for the World Health Organisation and samples will be despatched shortly. A trial of the behaviour of picture varnishes has been arranged on behalf of the National Gallery.
3 **Standardisation, Specifications etc.**	(a) J.S.C.C. Sub-Committee on Climatic, Shock and Vibration Testing		B A	Ministry of Defence.	A meeting of the Sub-Committee is to be held early this year to consider comments on the draft specification.

EXPLOSIVES

XX	**SOLID ROCKET CHARGES**					
1	**Charges for Unguided Weapons**	Use of plastic propellant for the 2-inch A/C Rocket Motor	(AW.246 OR.1099)	1 A 1.2B	E.R.D.E.	During the quarter ended 30th September, 62 Motors were filled and supplied to A.R.D.E. for firing. The occurrence of occasional bursts in firing at -40°F. is being investigated; results are not yet conclusive but it appears that a smaller igniter can be used, and, as expected, bad degreasing of the motors prior to filling leads to poor adhesion of propellant to the motor walls with consequent failure in firings at -40°F.
2	**Charges for Guided Weapons**	Plastic Propellant Boosts for D.G.W.R.D.	(GD.16, OR.1088, GW/B(a)1)	1 B 1.1B	E.R.D.E.	During the quarter ended 30th September, 98 Type II 5-inch light alloy motors were filled with R.D.2201 and 47 with R.D.2301. 9,460 lb. of various plastic propellants was supplied to R.A.E./R.P.D. for filling into experimental motors.
		LOKI 3-inch A/A Rocket Motor: use of plastic propellant		1 B 1.2B	E.R.D.E.	Filling studies is progress.
		Auxiliary Power Units for "Blue Sky"		1 B 1.2B	E.R.D.E.	Extruded double-base propellant charges, platonised with red lead have been supplied for use in the "Blue Sky" turbo-alternator. Further development is required because the burning rate is slightly low.
3	**Inhibiting Coatings**					
3.1	**for Cordite Charges**	(a) Use of polyester resins	(OR.1126 " 1099 " 687)	A A 2.1	E.R.D.E.	Work progressing; nothing fresh to report.

	(b) Screw-extrusion coating with ethyl cellulose	(OR.1126 " 1099 " 687)	A B 2.1	E.R.D.E.	Nothing fresh to report; further work depends on delivery of a positive haul-off apparatus which is on order.
	(c) Use of cellulose acetate of low acetyl value EMR. 6/Plas/362	(OR.1126 " 1099 " 687 A.5064)	A A 2.1	E.R.D.E. British Celanese	Preliminary trials with extruded tubes of ca. 1.8 ins. external diameter of low acetyl C.A. (acetyl value 38-39 as combined acetic acid) indicate that the normal stress relief method of application to cordite charges can probably be used. Possibilities of improving resistance to moisture absorption are being studied.
	(d) Use of Polyvinyl Chloride	(OR.1126 " 1099 " 687)	A 2.1	E.R.D.E.	Good adhesion has been obtained between unplasticised polyvinyl chloride and cordite. The behaviour of the bond on temperature-cycling is under investigation.
	(e) Use of Plastic Q	(OR.1126 " 1099 " 687)	A 2.1	E.R.D.E. R.O.F. Chorley	Liaison has been maintained with R.O.F. Chorley on the adhesion of plastic Q to 3-inch cordite SU/K cruciform charges. It appears that, provided sufficient adhesive is left at the cordite/plastic Q interface after the rolling-on operation, no bonding failures should occur. Bond strength increases on storage.
3.2 for Pressed Charges	(a) Use of Rubber Sleeves EMR.6/Gen.1519	(A.5064)	A	I.C.I. Ardeer	Results using the rubber-sleeve/cellulose acetate wrapping method continue to be favourable.
	(b) Use of Cellulose Acetate	(A.5064)		"	Castor oil polyurethane, prepared in situ gives an excellent bond between pressed charges and cellulose acetate restrictive containers (inhibitors). Cycling trials on 5-inch charges inhibited in this way give encouraging results.

XX SOLID ROCKET CHARGES (Contd.)	(c) Use of polyester resins				An extensive programme of work on the use of cast maleate polyester resins is in progress. Inhibiting layers have been cast on various ammonium nitrate charges. Using resins filled with china clay, inhibited charges cycle satisfactorily between +60°C. and -20°C. but the bond between A.N./wax charges and the resin was not as strong as with other A.N. charges. The impact strength of these resins is, however, undesirably low.
4 Inspection Methods					
4.1 Radiography	Detection of flaws		A B 2.1	E.R.D.E.	A radiographic method has been developed for the inspection of a gas-producing unit loaded with an I.C.I. pressed propellant.
4.2 Ultra-sonic Testing	Detection of flaws in double-base propellants of various configurations		A B 2.1	E.R.D.E.	Application to the detection of flaws in 3-inch S.U./K cruciform charges has been successful. Examination of twelve charges which had been rejected by X-ray inspection at N.O.I.L., Caerwent, showed that only six had flaws. This was confirmed by slicing the charges. Several R.O.F's and Inspectorates are interested in obtaining equipment; development of a simplified model of the E.R.D.E. prototype is in hand.

XXI	**SOLID PROPELLANTS FOR ROCKETS**					
1	**Colloidal Propellants - Extruded**					
1.1	**Improved Manufacturing Techniques**	Extrusion of large charges: long parallel die		A B 2.1	E.R.D.E.	The tensile strength of propellant F.488/649 has successfully been raised to 1420 p.s.i. by increasing the nitrocellulose content to 55 per cent.; there is an accompanying large increase in elongation at break. Extrusion qualities are being examined. The ballistics of the composition remain unchanged.
1.2	**New Compositions**	(a) Cool compositions for fuel ejection		A A 2.1	E.R.D.E.	Charges with platonised burning rates of 0.17 and 0.21 in./sec. have been supplied to R.A.E./R.P.D. Rolling and extrusion characteristics are good. A further composition containing red lead as platoniser has been developed; variations in ballistics due to differences in commercially available red lead supplies will be insignificant.
		(b) Faster-burning platonised propellants		A B 2.1	E.R.D.E.	Composition F.488/807B containing lead stannate is being assessed in factory production; some trouble with roll-fires is anticipated. Extrusion quality in 2-inch rocket motor size is satisfactory.
1.3	**Physical and Mechanical Properties**	Mechanical properties at High Rates of Loading		A C 2.1	E.R.D.E.	Investigations are in progress on cordite SU, using a drop-test method. The ultimate tensile strength at high rates of loading is more than double that determined by normal methods but the extension at break is about halved.

XXI	**SOLID PROPELLANTS FOR ROCKETS** (Contd.)					
1.4	**Rates of Burning (Ballistics)**	Influence of purity and uniformity of lead compounds		A C 2.1	E.R.D.E.	Supplies of lead stannate have been further examined for reproducibility of ballistics in composition F.488/807B. Ten batches gave burning rates of 0.61 in./sec. between 800 and 1300 p.s.i. reproducible to 0.015 in./sec. Blending further reduces variation and appears to be a satisfactory method of overcoming this difficulty. Ballistics are sensibly temperature invariant between -40°C. and +60°C.
2	**Colloidal Propellants - Cast**					
2.1	**Improved Manufacturing Techniques**	Tubular casting powders		D	E.R.D.E.	Nothing fresh to report.
2.2	**New Compositions**	(a) Improvements in storage life		A B 2.1	E.R.D.E.	Checks on the 80°C. cracking test have confirmed the reliability of the method. The deleterious effect produced by replacing 2-nitrodiphenylamine by carbamite in composition C.P.3. has been shown comparable with that with extruded propellants. Tests on a series of propellants containing red lead as platonising agent and only one non-explosive plasticiser have shown that dimethyl and diethyl pthalates give propellants of comparatively long cracking lives, whilst with pentaerythritol acetate - propionate the life is much reduced. The reduction is probably due to formation of lead acetate which is known to produce a short

					cracking life. Replacement of lead stearate by lead carbonate in composition C.P.3. considerably increases cracking life.
	(b) Development of cast propellant of low burning rate	A B	2.1	E.R.D.E.	Increase of carbamite content from 0.7 to 1.0 per cent reduced the plateau burning rate of composition ABL/M511 from 0.16 to 0.15 ins./sec. with the plateau range raised from 440 - 860 p.s.i. to 570 - 1400 p.s.i. Replacement of 2-nitrodiphenylamine in C.P.3. propellant by carbamite lowered the plateau to the slightly lower range 1000 - 2300 p.s.i.
2.4 Physical Properties	(a) Permeability of cast propellants to gaseous decomposition products (1) Nitrogen	B	2.1	E.R.D.E.	Results of earlier work on cordite SU/K have been confirmed. Work is being extended to platonised compositions; results with C.P.3. over the range 20-80°C. gave an activating energy of 12.4 K.cal/mole. The permeability figure (Q) for C.P.3. at 20°C. is 2.0×10^{-11} as compared with 4.3×10^{-11} for SU/K.
	(b) Thermal stresses in relation to charge design	A	2.1	E.R.D.E.	Photoelastic studies at 50°C. on models representing charges of multiconcentric and dumbell design have shown that no advantage is to be gained by increasing presently-specified corner radii (0.06 in.). The duration of maximum stress was much greater with the multiconcentric shape which suggests that the greater liability to cracking of charges of this design on temperature cycling is due to the lower shear strength applicable to the longer time of loading. Shear strengths of CDB propellants over a range of times of loading are being determined.

XXI	**SOLID PROPELLANTS FOR ROCKETS** (Contd.)					
3	**Plastic Propellants**					
3.1	**Improvements in Manufacturing Methods**	Elimination of rolling: the Ko-Kneader incorporator		A A 2.1	E.R.D.E.	Dry mixtures of ammonium perchlorate and ammonium picrate are too sensitive to friction to be metered by screw-feeding into the Ko-Kneader continuous incorporator. Alternative feed arrangements are being examined. A batch of R.D.2311 (containing no picrate) was successfully made using perchlorate of pass 10, retained 60, sieve size; negligible particle breakdown occurred. Tests on other types of propellant are being carried out.
3.2	**New Compositions**	Development of slow burning compositions for sustainer motors: use of cellulose acetate and oxamide as coolants		A B 2.1	E.R.D.E.	In progress: nothing fresh to report.
3.3	**Physical and Mechanical Properties**	(a) Influence of particle size range of ammonium perchlorate		A 2.1	E.R.D.E.	French ammonium perchlorate of pass 10, retained 60, mesh size, has a narrow, reproducible, particle size range and is attractive to use because of its free-flowing properties and general ease of handling. Trial mixes of plastic propellant have been made in the Baker-Perkins and Winkworth incorporators (see also 3.1) with and without rolling; in all cases little breakdown of perchlorate particles occurred and the propellants were sticky and had a high flow value.

		(b) Thermal diffusivity of plastic propellant and its ingredients				The thermal conductivity and specific heat of ammonium nitrate show abrupt changes in passing through the 32°C. transition point. With propellants containing ammonium nitrate thermal conductivity also depended on the number of times they had been cycled through this transition point. This may be due to loss of adhesion between crystals and binder. Correlation of thermal conductivity with other physical properties is being attempted.
3.4	Rate of Burning (Ballistics)	Assistance to R.O.F. Bridgwater on control of ballistics in manufacture		A B 2.1	E.R.D.E. R.O.F., Bridgwater	(1) Six tons of R.D.2304 has been successfully blended with 6 tons of slow-burning R.D.2307 at Bridgwater. (2) Experimental techniques used in the determination of strand-burning rates at E.R.D.E., Bridgwater and R.A.E./R.P.D. are being compared by using standard batches of propellant. Unlike results with cordite, no difference in burning rate is observed depending on whether the strands are fired immediately after pressurisation of the bomb or five minutes later.
3.5	Flash Suppression in Rocket Motors	Evaluation of various metallic oxides and compounds		A 2.1	E.R.D.E.	Copper oxide and copper chromite have previously been shown to be good flash suppressants. Other copper compounds are now being evaluated. Copper chromate appears promising and compositions containing this catalyst will be evaluated.

XXI	**SOLID PROPELLANTS FOR ROCKETS** (Contd.)					
4	**Pressed Charges**	EMR. 6/Gen/1519	(A.5064)			Virtually the whole of the pressed charge development is being carried out by I.C.I., Ardeer under contract.
4.1	**Ingredients**	(a) Alternatives to guanidine nitrate fuel		1	A	I.C.I., Ardeer.	The use of guanidine nitrate has been abandoned apart from outstanding requirements for firings, and development effort is now concentrated mainly on ammonium nitrate/wax compositions, which have higher specific impulses and are generally very promising. (See page 8).
		(b) Improvements in the method of associating potassium nitrate with ammonium nitrate			A	I.C.I., Ardeer.	The use of "wet annealed" mixtures of ammonium nitrate/potassium nitrate appears to prevent permanent expansion of ammonium nitrate/wax charges on temperature cycling. All expansions are reversible and dimensional stability is excellent.
4.2	**New Compositions**	(a) Ammonium nitrate/ hydrocarbon wax		1	A	I.C.I., Ardeer.	Mixtures of ammonium nitrate and Cornelius wax which are nearly oxygen-balanced are insensitive to friction and impact and non-explosive in the pressed form when heavily primed. These are now being studied with the aim of optimising specific impulse. Esso Amber wax appears to be a promising substitute for Cornelius wax and is being investigated in 5-inch motor size. Abril wax is unsuitable for use with ammonium nitrate; such compositions are relatively thermally unstable.

	(b) Ammonium nitrate/ anthraquinone		B B	I.C.I., Ardeer.	Investigations on ballistic and chemical stability are in progress. Reproducible ballistics can be obtained after long-term hot storage.
	(c) Ammonium nitrate/ urethane rubber			I.C.I., Ardeer.	Work on the use of castor oil polyurethane as a fuel continues. Processing difficulties are encountered; these are aggravated by the use of wet-annealed ammonium nitrate. Temperature cycling results to date are satisfactory.
	(d) Ammonium nitrate/ bitumen			I.C.I., Ardeer.	With any given grade of Mexphalte bitumen, ballistic properties were little changed by varying the oxygen value. Pressing and ignition of 5-inch charges are difficult, but temperature cycling is satisfactory in general.
	(e) Ammonium nitrate/ pitch			I.C.I., Ardeer.	Powdered compositions containing hard pitch could only be pressed at elevated temperatures. When the composition was granulated at 5-tons/sq.in., pressing was successful at room temperature.
	(f) Ammonium nitrate/ miscellaneous fuels			I.C.I., Ardeer.	Dinitronaphthalene and p-nitroaniline have suitable pressing properties and are being investigated. Acetanilide is being re-investigated but the burning rate appears to be subject to large variations with pressure. Panilax, an aniline/formaldehyde resin gives compositions of burning rate up to 0.44 in/sec. at 1000 p.s.i. and pressure exponents of the order 0.55; the calculated S.I. of an oxygen-balanced composition is 222 secs. at 1000 p.s.i. with flame temperature 2420°K.

XXI	**SOLID PROPELLANTS FOR ROCKETS** (Contd.)					
4.3	**Ballistics**	(a) Ammonium nitrate/ wax charges				23 large-scale firings in heavy-weight motors have been carried out in support of the Staghound motor development with promising results. High ignition peaks have been traced to erosive burning which can be eliminated by taper-boring the charge at the nozzle end.
		(b) New catalysts to give greater ballistic flexibility				Organo-metallic complexes in which fuel and catalyst are combined chemically are being investigated for use in ammonium nitrate propellants. The copper complexes, copper oxinate and Monastral Blue gave high burning rates and high pressure exponents. A series of chromium complexes gave high rates and low exponents, and of these, ammonium tricatechol chromate is sufficiently promising for work on the 5-inch scale. A range of simple inorganic compounds of the transition metals was investigated without finding any catalyst as useful as ammonium dichromate.
4.4	**Mechanical Properties**	(a) The effect of small amounts of water				The beneficial effect of the addition of small amounts of water (up to 0.2 per cent.) on the resistance to temperature cycling has been confirmed on 17-inch charges.
		(b) Compressive strength				4.6 inch charges of ammonium nitrate/wax propellants show considerable contraction in length when subjected to applied compressive stresses of 6 to 20 lbs./sq.in. and temperature cycled from +60 to -40°C.

					Similar deformations, which increased with time, occurred in continuous storage at 60°C. under compressive loading. This further demonstrates the need to avoid the normal method of holding charges in the rocket motor by compressive loading (see page 10).
5. **Experimental Types**					
5.1 **Elastic Composite Propellants**	(a) Ammonium nitrate/ natural rubber systems EMR.7/Amm/2931		A A 2.1	Monsanto Chemicals, Ruabon. E.R.D.E.	Propellants made from coarse ammonium nitrate with the aim of avoiding dewetting cracks gave unsatisfactory ballistic results; it appeared that some of the oxidiser was being ejected through the nozzle. It is doubtful if case-bonded charges can be developed, although loose, cartridge-type charges are still a possibility provided ageing difficulties can be overcome.
	(b) Ammonium nitrate/ p.v.c. systems			"	The upper safe temperature limit for curing appears to be too low to allow the physical properties of the p.v.c. to be optimised. Work is now being reorientated towards loose charges.
	(c) Ammonium nitrate/ polyvinyl butyral systems			"	Experimental batches of propellant have been made up. Work is in an early stage.
	(d) Development of new elastomers			"1	Investigations on the development of chain-extended polyurethane rubbers, which have shown promise in U.S.A. for use in composite propellants, have commenced. The polymerisation of glycidyl nitrate is being studied.

XXII PROPELLANTS FOR ORDNANCE	(a) Charge for Q.F. 3-in. 70 Gun	(Ad.359)	1 B 1.1B	E.R.D.E. A.R.D.E.	At the 9th Admiralty/Bu.Ord. conference, attended by E.R.D.E. representatives, the U.S. Navy accepted the 55% picrite propellant F.527/178/2P as suitable for standardisation, though a small change of size may be necessary to compensate for differences in U.S. and U.K. ammunition components. The interim standard lot of U.K. propellant is giving unexpected gun-to-gun variations and it is being examined for homogeneity.
	(b) Charge for Q.F. 40 mm./L70 gun	(A.4513)	1 A 1.1B	E.R.D.E. A.R.D.E.	Intensive investigation to develop a less erosive propellant is in progress. Cordite NQ/M gives about half the barrel life of the Bofors powder. Three cooler propellants are being investigated: 1. Cordite N. The required ballistics cannot be obtained with tubular propellant and preliminary firings with multitubular indicate that an increase in propellant force will be required. It is very desirable to develop a charge of double-base propellant as this is the only type at present suitable for R.O.F. production. 2. NH Moderated and unmoderated charges of the American NH composition are being investigated. 3. Imitation Bofors Propellant. Composition F.452/132 (96% nitrocellulose, 3% dibutylphthalate, 1% diphenylamine, moderated with 3% methyl centralite) is ballistically suitable and larger quantities are being manufactured for a wear trial and more comprehensive ballistic firings.

(c) Gun for medium tank No.2	(A.2727)	1 R 1.1B	E.R.D.E. A.R.D.E.	E.R.D.E. is maintaining close liaison with A.R.D.E. on the propellant aspects of the various solutions under consideration.
(d) Charge for Q.F. 4-in. full calibre gun	(A.4505 A.4701)	1 B 1.1B	E.R.D.E. R.O.F. Bishopton	Single-shot firings in a third-quarter gun indicate that the flashless performance of composition F.527/197/M is satisfactory. Conflicting statements have been made on flashless performance in rapid fire and an authoritative user opinion will be obtained at the earliest opportunity.
(e) New propellant types		A C 2.1		Two cool non-picrite types of composition are under investigation: 1. <u>Containing cellulose acetate and triacetin as main coolants.</u> Successful firings have been conducted in the Q.F. 25 pdr. Such compositions would provide replacements for cordite WM which is unnecessarily erosive in many applications. 2. <u>Containing oxamide as main coolant.</u> Theoretically this type of composition is as flashless as picrite compositions of equivalent flame temperature. Samples have been manufactured for closed-vessel investigations of the burning characteristics.

XXIII PROPELLANTS FOR SMALL ARMS	(a) Development of propellant for the Aden high velocity round EMR's 6/Gen/1002 6/Gen/1993	(O.R.1007) (A.W. 65)	1 A 1.1B	I.C.I. (Powfoot & Ardeer)	Recent lots of Powfoot-manufactured N.R.N. propellant have given observed velocities of 2,540 to 2,550 f/s at acceptance proof. Modifications of the manufacturing process, to improve the bulk density and ballistic efficiency, are being investigated. An increase in velocity of 150 to 200 f/s could be obtained by using a double-base propellant, with or without R.D.X. or P.E.T.N. in addition. Promising moderation of double-base propellant has been obtained with picrite/carbamite complex or ABRAC ester gum. All such propellants, however, give excessive pressures when fired at case capacity at low temperatures.
	(b) Development of propellants for the 7.62 mm. automatic rifle EMR. 6/Gen/864	(A.3002)	1 A 1.1B	I.C.I. (Powfoot & Ardeer)	All Powfoot production lots of N.R.N. have been accepted for fillings. The ballistic requirements for ball ammunition are being met. However, a cooler propellant will be required for the light machine gun, which uses the same ammunition as the rifle, and one of higher density for tracer ammunition.
	(c) Ball Powder: development of manufacturing method		A B 2.1	E.R.D.E.	Study of the manufacture of base grain and finished coated powder is continuing. Analytical difficulties and discrepancies between determined and expected calorimetric and nitrogen values have been traced to residual solvent in the base grain. The solvent can be easily removed by boiling for a few hours in fresh water. Several powders, produced

by coating base grain with nitroglycerine and dibutylphthalate or with dibutylphthalate alone, have met the specified ballistics of the 7.92 mm. weapon. A good degree of manufacturing reproducibility has been achieved using a single batch of base grain.

XXIV LIQUID PROPELLANTS					
1 Hydrogen Peroxide	(a) Stability Studies		A B 2.1	E.R.D.E.	The rate of decomposition at 35°C of non-stabilised 86% hydrogen peroxide has been studied in aluminium vessels, using the automatic gasometric apparatus. The lowest rate of decomposition is observed when the vessel is etched with caustic soda solution, pickled in concentrated nitric acid and heated in H.T.P. (non-stabilised). Apparently identical vessels do not give the same rate; the fastest is about double the slowest. Boiling a conditioned vessel with water, which converts the surface film of aluminium oxide to hydroxide, increases the rate about 10-fold. There is a diurnal variation in rate which appears to be correlated with changes in atmospheric pressure. The rate of decomposition of stabilised H.T.P. increases with increase in the surface/volume ratio of the vessel.
	(b) Examination of specification test methods		A B 2.1	E.R.D.E.	The small tube test and the gasometric test on a 25-cc sample at 100°C have been compared. The latter is more reliable, particularly for non-stabilised H.T.P. or H.T.P. type A from which all tin has deposited. In testing tin-free H.T.P. very careful conditioning of the vessel is essential. Whatever the original condition of a vessel, repeated treatments by boiling with the H.T.P. under test lead to progressively lower rates of decomposition until finally a value characteristic of the H.T.P. is obtained.

						Difficulty has been experienced in estimating tin by the specification method. It appears that complete destruction or removal of hydrogen peroxide before the polarographic determination is essential.
	(c) General physico-chemical research on high test peroxide EMR.7/Chem/59		C	B 2.1	Kings College, Newcastle-upon-Tyne.	Fundamental studies on the influence of various factors on the stability and stabilisation of H.T.P. are in progress.
2 **Applications of liquid propellants**	(a) Hydrazine/Hydrazine nitrate/water as bi-propellant for tank guns	(A.2504)	2	R 1.2B	Shoeburyness	Vulnerability trials in fighting vehicles have been planned. Supplies of materials are awaited.
	(b) Nitric ester mono-propellants for guns	(A.2504)	2	B 1.2B	E.R.D.E.	Theoretical assessment of performance by calculation from thermochemical data may be inaccurate as the flame temperature is too low for the attainment of chemical equilibrium. Closed vessel firings of ethyl nitrate, at a peak pressure of 10 t.s.i. and analysis of the products show that equilibrium is attained. But in the case of isopropyl nitrate, peak pressure 6 to 7 t.s.i., very much more carbon is formed than would be expected.
	(c) R.F.N.A./kerosine bi-propellant for rockets EMR.7/Chem/142		C	2.1	C.R.L. D.S.I.R.	The special techniques developed at C.R.L. have been applied to the examination of films formed on aluminium and aluminium alloys by immersion in R.F.N.A. containing hydrogen fluoride as corrosion inhibitor. It has been shown that the films are not continuous but are discrete particles of aluminium fluoride mixed with one or other of the forms of hydrated alumina. The work has been completed.

XXV	**COMBUSTION RESEARCH**					
1	**Theoretical studies**	Thermochemistry and stability of molecules EMR.7/Chem/136		C B 2.1	Manchester University	Work in progress aimed at provision of more precise thermo-chemical data on e.g. fluorocarbons.
		EMR.7/Explve/62		C B 2.1	University College of North Staffs.	Work in progress aimed at resolution of anomalies in thermochemical data and molecular structures of nitro-bodies.
2	**Gaseous Systems**	Thermal ignition and combustion in the vapour phase of self-combustible compounds EMR.7/Chem/134		C E 2.1	Cambridge University	Work on flame propagation in hydrazine vapour has been suspended, due to loss of staff.
3	**Liquid/Gaseous Systems**	Combustion of n-propyl nitrate		C B 2.1	E.R.D.E.	E.R.D.E. Report 16/R/55, "Flame Decomposition of the Propyl Nitrates", has been issued.
4	**Solid and Colloidal Systems**	(a) The effect of lead compounds on the thermal ignition of nitrocellulose		B B 2.1	E.R.D.E.	The effect of 5 per cent. of various lead compounds on the time delay in the ignition of N.C. pellets (12.2 per cent. nitrogen) at 200-300°C. has been studied. The results for NC alone and containing lead stannate, lead 2-ethyl hexoate or lead oxide gave the usual Arrhenius straight line relationship. Lead 2-ethyl hexoate and lead stannate were slightly more effective in reducing the induction period at the higher end of the temperature range whereas lead oxide was more effective at the lower end. With lead salicylate the graph consisted of two straight lines intersecting at a point corresponding to 251°C.; above this the effect of salicylate was similar to that of lead oxide, whilst below the effect decreased rapidly.

(b)	The effect of lead compounds on the combustion of nitrocellulose	B C 2.1	E.R.D.E.	Results previously reported for the combustion of NC strands with and without lead 2-ethyl hexoate at atmospheric pressures have now been extended to higher pressures. The burning rate with lead 2-ethyl hexoate is increased only at pressures below 700 and above 1500 p.s.i. At atmospheric pressures the gas temperature near the burning surface is increased from 600 to 750°C. by the addition of the lead compounds, whilst the temperature of incandescent carbonaceous particles on the burning surface is increased from 700 to 800°C. Variation of temperature of hot-spots with pressure is being studied.
(c)	The platonisation of double base propellants: effects of oxides of various metals etc.		E.R.D.E.	The effects of 0.1 gm atom of various metal oxides on the combustion of a standard double-base propellant of cal. val. 830 cal/gm have been studied. Lead oxide produced a marked mesa effect, increasing the rate of burning below 1000 p.s.i. and increasing it above 1200 p.s.i. Cupric and cobaltic oxides gave an increased rate at all pressures up to 2500 p.s.i. Ferric and zinc oxides increase the rate only above 700 and 1100 p.s.i. respectively. The largest increase was produced by cupric oxide, which doubled the rate even at 2000 p.s.i. The addition of 1.3 per cent. by weight of ammonium mono-hydrogen phosphate, a substance known to promote carbon formation in the burning of cellulose esters, but to inhibit oxidation of carbon, decreased the burning rate by about 30 per cent.

XXV COMBUSTION RESEARCH (Contd.)

			at all pressures. This supports the view that carbon formation and the heat involved in its oxidation are important factors in the determination of the burning rate.
(d) Solid and binary systems based on ammonium perchlorate: use of oxygenated fuels		E.R.D.E.	The pressure dependence of the rate of burning of carbonaceous fuels with ammonium perchlorate can be reduced by increasing the oxygen content of the fuel. Thus fuels such as paraformaldehyde and acetates of polyhydroxyalcohols give zero or negative exponents, and polyethylene glycols, polyesters and polyamides all effect reductions. The physical properties of these fuels, however, are unsatisfactory for their use as binders in plastic propellants, but preliminary investigations indicate that selected linear polymers, made by chain lengthening low molecular weight bifunctional polyglycols and polyesters by reaction with di-isocyanates, might have satisfactory visco-elastic properties. The variation of viscosity, brittle point and second-order transition point with the molecular weight of these polymers is being studied.

XXVI	SENSITIVENESS AND DETONABILITY OF PROPELLANTS, EXPLOSIVES AND INITIATORS				
1	Evaluation of Test Methods	(a) Gap test studies	B C 2.1	E.R.D.E.	1. Liquids. Replacement of the top plate by a "plastic gauge", which behaves similarly to a piezoelectric transducer, has enabled measurements to be made of the interval between the initiating shock and the main explosion. The delay increases as the gap is increased but there is no correlation between the delay at the "critical card value" and the rate of energy release. However, for a series of explosives, at a fixed card value less than the critical, the delay varies inversely as the rate of energy release. Delays ranging from 100 to 1,000 microseconds have been observed. 2. Solids. An investigation of the mechanism of the gap test as applied to solids has been started using charges of pressed T.N.T. 6 inches long (Scale II). The critical card value is about 24. One additional card, added to the stack or inserted in the charge within 0.25 inch of the stack, reduces the probability of explosion from 90% to 10%. A 3/16 inch hole at the centre of the extra card, but not at the edge, destroys its effect. Many cards inserted in the body of the charge, e.g. not less than 25 cards at 3 inches from the initiated end, have no effect. The delay is one to five microseconds.

XXVI	SENSITIVENESS AND DETONABILITY OF PROPELLANTS, EXPLOSIVES AND INITIATORS (Cont'd.)					
2	Impact and Friction Sensitiveness	(a)	Lubricants etc., for use with H.T.P.	A R 2.1	E.R.D.E.	A number of chlorofluorocarbons, suggested by de Havilland Engine Co.Ltd. as pressure transmitters in indicators used with H.T.P., have been tested in admixture with H.T.P. for sensitiveness to impact. The least sensitive mixture was given by "Arcton 9" (trichlorofluoromethane), tested at 0°C. (boiling point 24°C.).
		(b)	Mixtures of varnishes and H.E.	B E 2.1	E.R.D.E.	The effect on the sensitiveness of adding 5% of powdered varnish VF.588 to a number of standard explosives has been determined. Some sensitisation was observed in each case, the most serious effect being with R.D.X. and R.D.X./T.N.T. R.D.X., but not R.D.X./ T.N.T. nor Torpex 5, was also considerably sensitised by copal varnish.
		(c)	Plastic propellant	B B 2.1	E.R.D.E.	The sensitiveness of a number of plastic propellants has been examined at various temperatures from 20 to -20°C. Preliminary results indicate that sensitiveness is increased at lower temperatures.
		(d)	Development of method for determining sensitiveness to friction EMR.7/Exptl/648	C B 2.1	Cambridge University	Work in progress under Dr. F.P. Bowden. The aim is to develop a method in which no impact component is involved.

3 **Sensitiveness to Electric Discharge**	(a) Effect of graphite on sensitiveness of initiators		B B 2.1	E.R.D.E.	Work is continuing on the effect of coating the various forms of lead styphnate with graphite. As the amount of graphite on R.D.1302, 1303 or 1318 is increased the minimum ignition energy at first decreases and then increases to several times that of the untreated initiator. A similar effect is obtained when powdered graphite is mechanically mixed with R.D.1303. However, when powdered graphite is deposited on R.D.1303 the minimum energy rises continuously as the amount of graphite is increased.
4 **Propagation Studies**	(a) Detonability of propyne (methyl acetylene)		A C 2.1	E.R.D.E.	Propyne will not propagate an explosion under heavy confinement at atmospheric pressure at -23°C. (boiling point). There is therefore complete confidence in the detonation trap previously recommended.
	(b) Sensitiveness of H.T.P.		A A 2.1	E.R.D.E.	Various concentrations of aqueous hydrogen peroxide, (i) free from organic matter, (ii) containing added diethylene glycol, (iii) evaporator residues from the Laporte organic-process pilot plant, have been examined by gap and propagation tests at 65°C. The 'safe' line, i.e. not more sensitive than iso-propyl nitrate, runs linearly from 18.8 g.p.l. of carbon in 65% hydrogen peroxide to zero in 80%. No discernible difference is shown by gap and propagation tests between finished organic-process H.T.P., containing 0.15 g.p.l. of carbon, and electrolytic H.T.P.

XXVI SENSITIVENESS AND DETONABILITY OF PROPELLANTS, EXPLOSIVES AND INITIATORS (Contd.)	(c) Mechanism of initiation and growth of explosions EMR.7/Exptl/648		C B 2.1	Cambridge University	Work in progress under the direction of Dr. F.P. Bowden.

XXVII	**CHEMISTRY OF PROPELLANT INGREDIENTS**					
1	**Production of Nitro-guanidine**					
1.1	Calcium Cyanamide Synthesis	(a) Studies on the carbon monoxide/ ammonia/lime system		A B	2.1	E.R.D.E.	A literature survey of the kinetics of disproportionation of carbon monoxide to carbon and carbon dioxide has been started. Little information is available. The reaction appears to be slow on most surfaces, and on iron it is first order with respect to carbon monoxide.
1.2	Production of Ammonium Thiocyanate	Conversion of hydrogen sulphide to carbon disulphide EMR.7/Chem/96		C	2.1	University College, Swansea.	Studies on the direct conversion of hydrogen sulphide to carbon disulphide have been completed. The mechanism of reaction of hydrogen sulphide and carbon, with and without oxygen, has been elucidated. The yields obtained experimentally agree with those calculated from the thermodynamic data.
		EMR.7/Chem/82		C B	2.1	Imperial College, London.	The indirect conversion, by reaction of sulphur with carbon monoxide and with hydrocarbons, is under investigation.
1.3	Guanidine nitrate from urea	(a) Reaction of urea, ammonium nitrate and silica gel		A C	2.1	E.R.D.E.	Mixtures of urea (2 moles), silica (1 mole) and different amounts of ammonium nitrate have been heated at 200°C. for 2 hours. The best yield of guanidine nitrate (0.74 mole) was obtained with 2 to 3 moles of ammonium nitrate. The silica gel deteriorated during a few recycles; deposition of water-insoluble by-products reduced activity and caused foaming. Foaming

XXVII **CHEMISTRY OF PROPELLANT INGREDIENTS** (Contd.)					could be prevented by washing the silica with nitric acid but the activity was still low. The best treatment appears to be water flotation.
	(b) Thermal decomposition of urea and its derivatives EMR.7/Chem/181		C B 2.1	University of Edinburgh	Basic research in aid of synthesis of guanidine compounds from urea.
2 **Nitrocellulose**	(a) Thermal degradation of nitrocellulose in solution: effect of stabilisers		B C 2.1	E.R.D.E.	Addition of carbamite to a solution of nitrocellulose in cyclohexanone, up to 45% of the weight of nitrocellulose, has no effect on the rate of fall of viscosity at 60°C.
	(b) Improved Methods of stabilising nitrocellulose: effects of oxidised groups		B C 2.1	E.R.D.E.	The oxidation of aldehyde groups during nitration and stabilisation of dialdehyde oxycellulose is being investigated, but analytical difficulties are considerable. The carboxyl content of nitrocellulose, obtained by nitration in acids containing nitrous acid, tends to increase during stabilisation. Very little oxidation can be induced after nitration by "careless" drowning or drowning in sodium nitrite solution. Boiling of nitrocelluloses, derived from cotton oxidised with nitrogen peroxide, causes a greater loss of carboxyl at a nitrogen level of 12.2% than at 13.1%.
3 **Nitric Esters**	Kinetics of nitration of alcohols EMR.7/Explve/77		C B 2.1	Royal Holloway College.	Work is in progress to determine the mechanism of nitration of alcohols with a view to adding to existing knowledge of nitration processes and control.

4 **Minor Propellants Ingredients**	(a) Ballistic Modifiers	A R 2.1	Commercial supplies of the lead salts of 2:4-dihydroxybenzoic acid, succinic acid and catechol have been examined. Different samples of the first contained 0.1 to 11% of resorcinol.
	(b) Stabilisers	A R 2.1	Various nitrated diphenylamines and methylanilines are being prepared for evaluation.

XXVIII **CHEMISTRY OF HIGH EXPLOSIVES**					
1 **T.N.T.**	(a) Continuous nitration: study of impurities formed		A B 1.3	E.R.D.E.	The separation by paper chromatography of impurities in crude T.N.T. is being investigated. Likely impurities and the isomeric T.N.Ts are being synthesised. The physical and chemical properties of "white compound" are being further studied. Melting point is not a good criterion of purity; samples treated in different ways melt at different temperatures but they give the same X-ray powder diagram. Conductimetric and potentiometric titrations show that "white compound" is a moderately strong dibasic acid with a molecular weight of 466.
	(b) Effect of heat		C B 1.3	E.R.D.E.	Paper chromatography is being applied to the separation of the dark substances formed when some samples of T.N.T. are heated.
	(c) Incidents in R.O.Fs.		A B 2.1	E.R.D.E.	The circumstances of a fire in a pre-sulphite washer at Pembrey have been investigated. The lead salt of "white compound," which is known to have a figure of insensitiveness of 18, was found in deposits on the lead walls of the washer and to a lesser extent in the scum floating on the wash water.
2 **R.D.X.**	Improvement in manufacturing methods: stabilisation of reaction mixture after dilution		A C 1.3	E.R.D.E.	Work in abeyance in favour of H.M.X. investigations.

3 **H.M.X.**	Study of methods of preparation		A B 1.3	E.R.D.E.	Intermediates present in Bachmann and Picatinny reaction mixtures have been further investigated. H.M.X. is fairly soluble in 98% nitric acid. Dilution of a saturated solution at 20°C. to 55% nitric acid gave fine H.M.X. (5 to 10 microns), whose polymorphic state depended on the rate of precipitation. Boiling this product gave well-formed beta H.M.X. crystals, of which 20% were larger than 100 microns and 60% smaller than 76 microns. In some instances a proportion of massive crystals of alpha H.M.X. were formed. The boiling reduced the acidity of the H.M.X., but not below 0.02% nitric acid. The grist of H.M.X., made by plant-scale percolation, could not be increased, but was decreased, by stirring in boiling 80% aqueous acetone. It has been confirmed by repetition of earlier experiments that percolation of H.M.X. with 70% aqueous acetone yields products containing large proportions of crystals in the ranges 300 to 600; with 20% acetone the grist obtained is 76 to 120 microns.

XXIX	CHEMISTRY OF INITIATORS					
1	Lead Dinitroresorcinate	Improvements in manufacture		A B 1.3	E.R.D.E.	R.D.1350, a free-flowing granular form of monobasic lead 2:4 dinitroresorcinate, appears to be less sensitive to impact and to propagate ignition less readily than R.D.1357 (the normal salt); it is therefore a candidate for the 30-mm. delay fuze requirement. Six months storage of R.D.1337 under water has not affected its physical form or sensitiveness. If functioning tests are equally satisfactory wet storage will be permissible, a great advantage in production and transport.
2	Lead Styphnate	(a) Preparation and properties of the polymorphic forms of monobasic lead styphnate		A B 1.3	E.R.D.E.	It has been shown, by grinding and re-testing, that the low electrostatic sensitivity of R.D.1349 (beta monobasic lead styphnate) is not a surface phenomenon (due to absorption) but is characteristic of the whole crystal. It is further desensitised by mixing with powdered graphite, whereas the alpha polymorph is sensitised by this treatment.
		(b) Preparation and properties of the polymorphic forms of normal lead styphnate		A B 1.3	E.R.D.E.	Arrangements have been made, with the co-operation of Canadian Arsenals Ltd., to supply N.O.L.(U.S.A.) with materials and information on processing for an investigation of R.D.1302/graphite in a primer application. The Indian authorities have been advised on difficulties experienced in the manufacture of R.D.1302.

3 **Lead Azide**	(a) Dextrinated lead azide: improvements in crystallisation and bulk density		A B 1.3	E.R.D.E.	An investigation of the effects of surface active agents is continuing. "Dispersol T" and the sodium salts of alpha and beta naphthalene sulphonic acids produce a marked improvement in the physical form of the product. The last two also increase the yield.
4 **Barium Styphnate**	Modification of crystal habit		I B 1.1B	E.R.D.E.	Barium Styphnate of modified crystal habit has been supplied to A.R.D.E. for fuze investigations.

XXX	**SPECIFIC APPLICATIONS OF INITIATORS**					
	(a) Delay compositions for small fuzes	(A.4153)	I	B	1.1B	E.R.D.E.	Samples of R.D.1316 (lead styphnate co-precipitated with methyl cellulose), prepared over a range of precipitation temperatures, have been supplied to A.R.D.E. for an investigation of the effects of ageing on the rate of burning.
	(b) Replacement of A1 mixture	(OR.1007) (AW. 65)	I	B	1.1B	E.R.D.E.	R.D.1652, a mixture containing R.D.1340 (a form of barium styphnate monohydrate), is much less sensitive to impact than A1 mixture and its use in 30 mm. electric caps has been approved (O.B.Proc. 38195). Assistance is being given to R.O.F. Swynnerton in starting up production and filling, and to D.C.I. in drafting a specification.
	(c) N.88 Gun-flash simulator	(A.1301)	3	B	1.1B	E.R.D.E.	R.D.1337 (normal lead 2:4 - dinitro-resorcinate co-precipitated with carboxymethyl cellulose) has been accepted for Service use, and a production unit has been established at R.O.F. Swynnerton.
	(d) Production of 6-gr ZY inversely loaded detonators		A	B	1.3	E.R.D.E.	The process of manufacture of R.D.1333 (lead azide co-precipitated with carboxymethyl cellulose) has been modified to yield a product of greater bulk density, which will facilitate production.
	(e) Incidents in R.O.F's.		A	B	2.1	E.R.D.E.	A Working Party has been set up in E.R.D.E. to investigate the causes of apparently spontaneous explosions of detonators in drying stoves at R.O.F's.

The surface deposits present in unfilled detonator shells have been examined by X-ray methods but they have not been identified. The re-assertion after pressing of typical detonator compositions and the coefficients of thermal expansion of the ingredients have been measured. The spark ignition of hydrazoic acid vapour at a pressure of about 2 cm Hg, both alone and mixed with air, has been investigated. The explosive limit appears to be between 7.7% and 10% (by volume) of vapour. Lead azide is readily sensitised by mercury fulminate; a mixture containing about 0.5% of fulminate is almost as sensitive to impact as pure fulminate. Sensitisation by 'A' composition is less marked and the addition of 2% is needed to bring the sensitiveness near to that of 'A' composition alone.

A report of the Working Party is about to be issued. While no clear evidence of the cause of the ignitions has emerged, new information has been obtained on the effects of nitrate contamination of fulminate used in conjunction with azide.

XXXI CHEMICAL ENGINEERING					
1 **Research**	(a) Heat transfer (gas to metal) at very high temperatures and moderate pressures		A C 2.1	E.R.D.E.	The experiments with a 5-fold excess of oxygen have given unexpected results in that a preliminary evaluation indicates that there is strong thermal radiation similar, in the neighbourhood of the injector, to that given by a luminous flame emitting black-body radiation.
	(b) Distillation EMR.7/Chem/157		C 2.1	University of Birmingham	Studies have been completed on the vapour-liquid equilibrium of the system nitric acid/sulphuric acid/ water and a report is awaited.
2 **Manufacturing Processes**					
2.1 Picrite (Nitroguanidine)	(a) E.R.D.E. Nitrolim process		A B 2.1	E.R.D.E.	The direct fusion and low-ratio nitration pilot plants were demonstrated to the American Cyanamid Co. Scientists from the company collaborated with E.R.D.E. staff in running the plants. This work is more fully reported on page 7.
2.2 R.D.X.	Studies related to R.O.F. hazards		A 1.3	E.R.D.E.	E.R.D.E. Report 13/R/55 "A study of the R.D.X. diluter icing-up problem, using a 4-lb/hour model plant", has been issued.
2.3 H.M.X.	Manufacture and crystallisation		A A 1.3	E.R.D.E.	The nitration plant has been run for 10 days on a 2-shift basis and about one ton of crude alpha H.M.X. has been produced. Re-crystallisation has been studied in laboratory glass percolators. Addition of a little water to the solvent increases the size of the crystals.

						Using a mixture of cyclohexanone and acetone, size increases with cyclohexanone content. A high temperature at the evaporating surface leads to small crystals. Laboratory results have not been reproduced on the plant percolator though a better product, i.e. containing a bigger proportion of crystals greater than 300 microns, has been made by reducing the steam-jacket temperature. About 1600 lb. of wet product has been accepted by the user. Trials of the Holston procedure, percolation with acetone/water, are being carried out at E.R.D.E. and R.O.F. Bridgwater. Fine H.M.X. is being produced by percolation with dilute acetone. Methods of size classification, by sieving and sedimentation, are being investigated.
2.4 T.N.T.			B E 1.3	E.R.D.E.	Nothing to report.
2.5 Liquid Oxygen	(a) Development of mobile oxygen and nitrogen plant	MX.13	2 A 1.1A	British Oxygen Engineering Co.	Consideration has been given to modifications to be incorporated in future production models. Since the War Office do not require machines to make <u>liquid</u> oxygen the six-stage air compressor may be replaced by one of four stages. Consequently a diesel engine, though more bulky, can replace the B.81 petrol engine with advantage.

XXXI **CHEMICAL ENGINEERING** (Contd.)	(b) Packed columns for liquid-air fractionation		A B 2.1	E.R.D.E.	Preliminary runs have been started on the 2.7-inch diameter experimental column, random packed to a depth of 12 inches with $\frac{1}{4}$-inch Dixon gauze rings, using a mixed feed of liquid oxygen/nitrogen.
2.6 **Acetylene**	Development of mobile dissolved-acetylene plant EMR.7/P. & Eq/455	MX.14	2 A 1.1A	British Oxygen Engineering Co.	Some cylinder-charging trials were carried out during the warm weather of last summer, and opportunity was taken to put the motor, gear box and compressor assembly through the same trials. The acetylene receivers were cooled with mains water. A satisfactory filling rate was achieved.

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